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Minteer et al.

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(54) **FLUID TRANSPORT SYSTEM FOR PREVENTING ELECTRICAL DISCHARGE**

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(51) **Int. Cl.**

H05F 3/00	(2006.01)
B64D 45/02	(2006.01)
F16L 25/02	(2006.01)
F17D 1/00	(2006.01)
F16L 9/14	(2006.01)

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CPC . ***B64D 45/02*** (2013.01); ***F16L 9/14*** (2013.01); ***F16L 21/065*** (2013.01); ***F16L 25/01*** (2013.01); ***F16L 25/025*** (2013.01); ***F16L 25/026*** (2013.01); ***F17D 1/00*** (2013.01); ***H05F 1/00*** (2013.01); *Y10T 137/8593* (2013.01)

(58) **Field of Classification Search**

USPC 361/218

See application file for complete search history.

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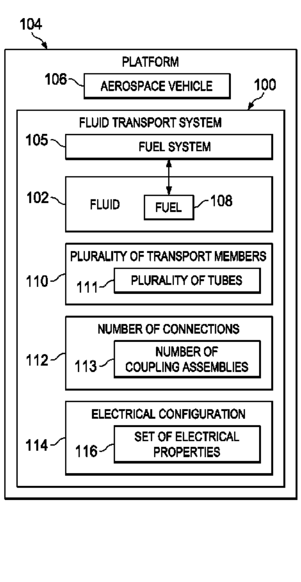
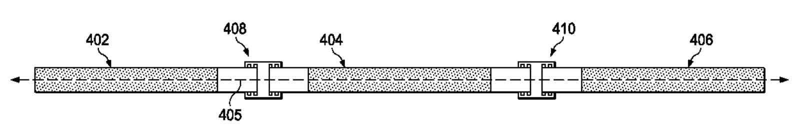
(57) **ABSTRACT**

A method and apparatus for reducing an intensity of an electrical discharge that occurs within a fluid transport system in an aerospace vehicle. The aerospace vehicle is operated. The fluid transport system in the aerospace vehicle is comprised of materials selected such that the fluid transport system has an electrical configuration. The intensity of the electrical discharge that occurs within the fluid transport system during operation of the aerospace vehicle is reduced to within selected tolerances by the electrical configuration of the fluid transport system.

20 Claims, 13 Drawing Sheets





(51) **Int. Cl.**

H05F 1/00	(2006.01)
F16L 21/06	(2006.01)
F16L 25/01	(2006.01)

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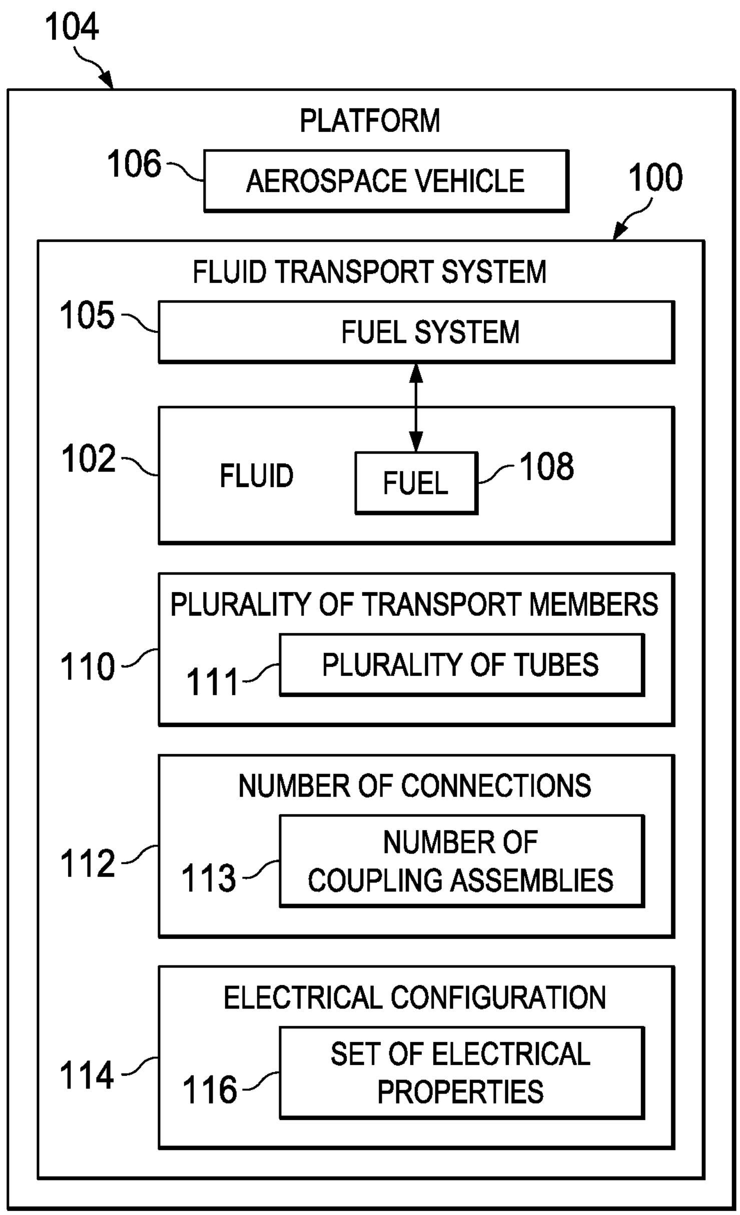

104
PLATFORM
106
AEROSPACE VEHICLE
100
FLUID TRANSPORT SYSTEM
105
FUEL SYSTEM
102
FLUID
FUEL
108
PLURALITY OF TRANSPORT MEMBERS
110
111
PLURALITY OF TUBES
NUMBER OF CONNECTIONS
112
113
NUMBER OF COUPLING ASSEMBLIES
ELECTRICAL CONFIGURATION
114
116
SET OF ELECTRICAL PROPERTIES

FIG. 1

FIG. 2

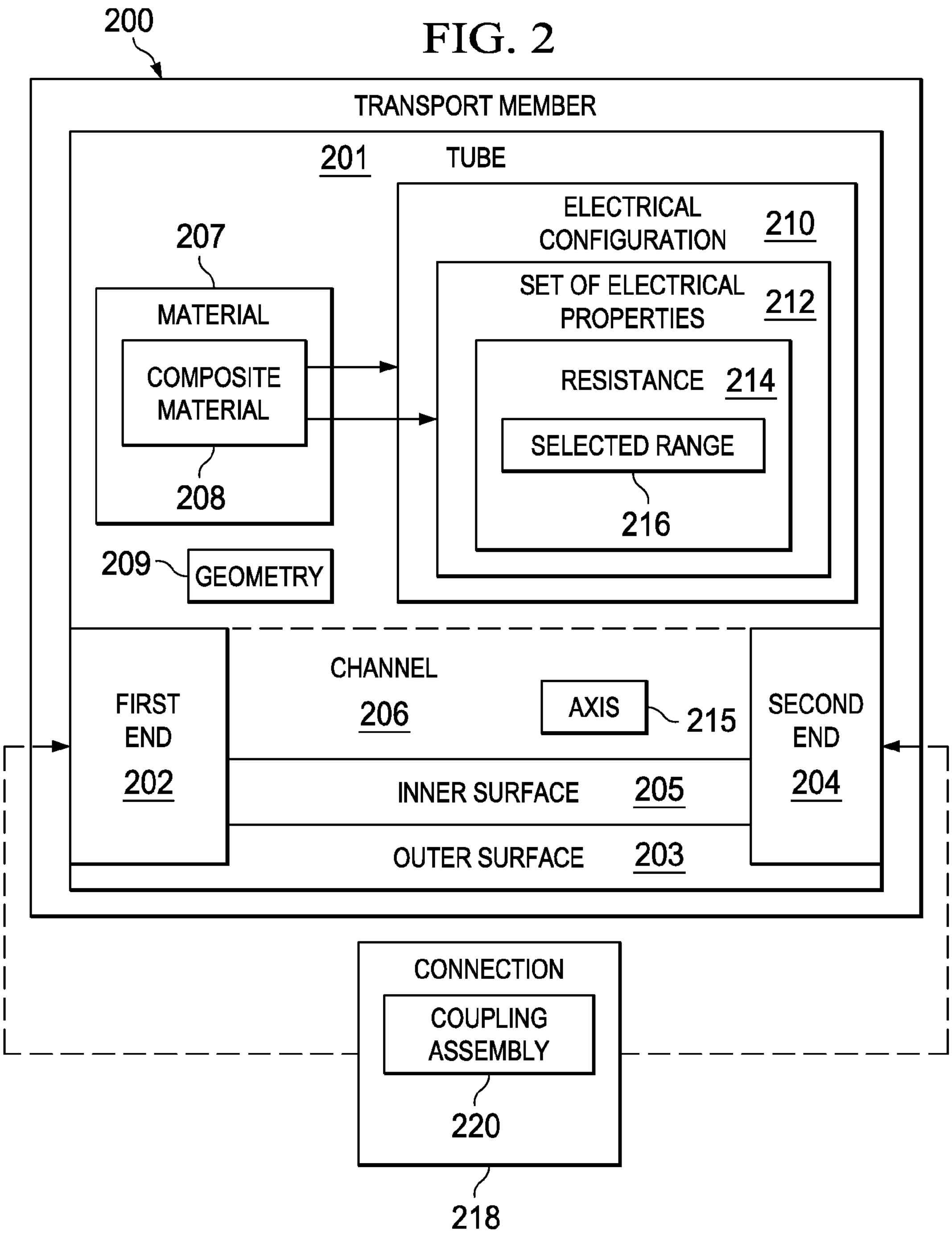
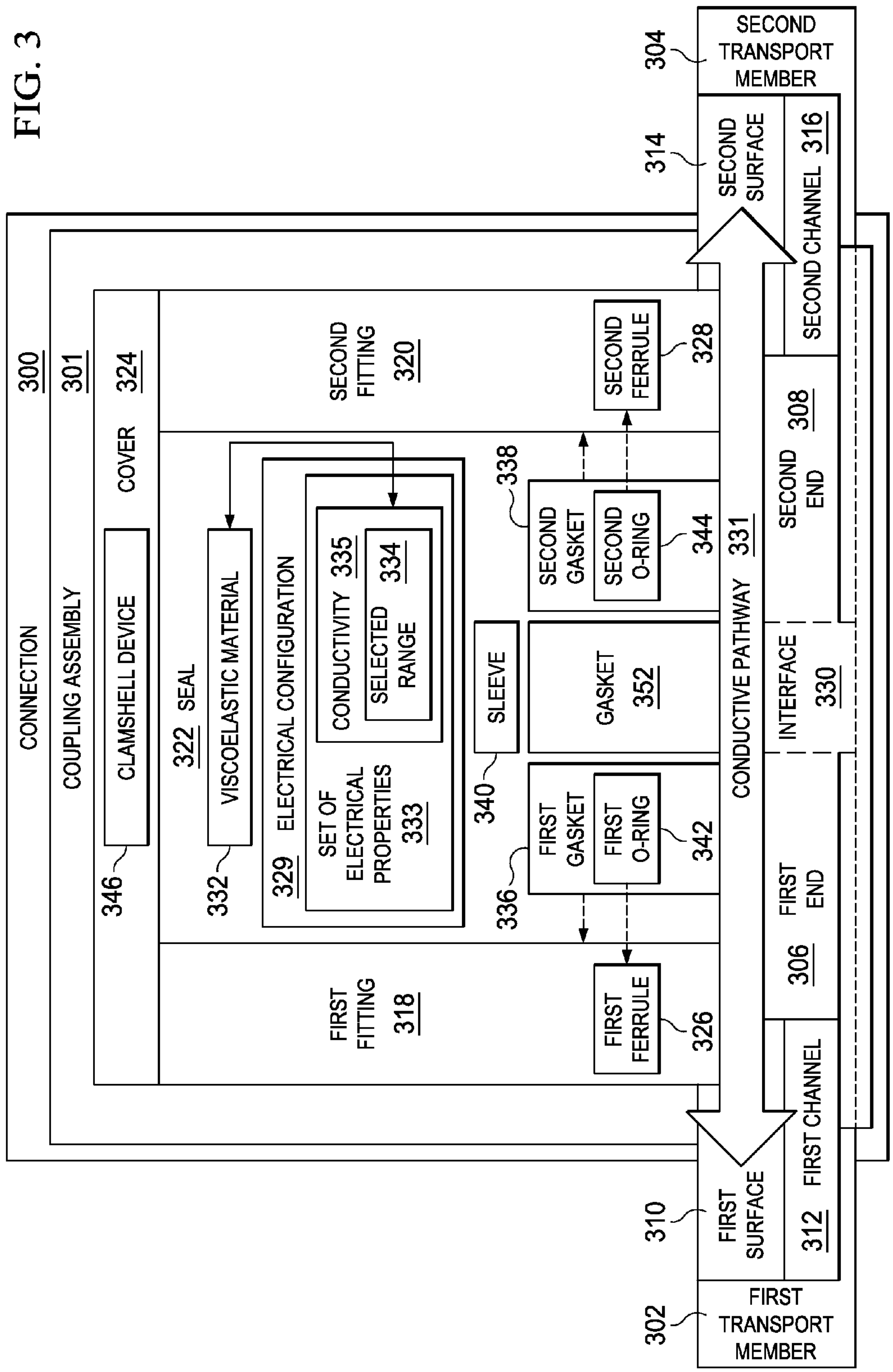

200
TRANSPORT MEMBER
201
TUBE
ELECTRICAL CONFIGURATION
210
207
MATERIAL
COMPOSITE MATERIAL
208
SET OF ELECTRICAL PROPERTIES
212
RESISTANCE
214
SELECTED RANGE
216
209
GEOMETRY
CHANNEL
206
AXIS
215
FIRST END
202
SECOND END
204
INNER SURFACE
205
OUTER SURFACE
203
CONNECTION
COUPLING ASSEMBLY
220
218

FIG. 3


CONNECTION 300
COUPLING ASSEMBLY 301
COVER 324
CLAMSHELL DEVICE
346
322 SEAL
VISCOELASTIC MATERIAL
332
ELECTRICAL CONFIGURATION
329
SET OF ELECTRICAL PROPERTIES 333
CONDUCTIVITY 335
SELECTED RANGE
334
SLEEVE
340
FIRST FITTING 318
SECOND FITTING 320
FIRST FERRULE
326
SECOND FERRULE
328
FIRST GASKET
336
FIRST O-RING
342
GASKET 352
SECOND GASKET
338
SECOND O-RING
344
CONDUCTIVE PATHWAY 331
FIRST END
306
INTERFACE 330
SECOND END
308
FIRST SURFACE
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FIRST CHANNEL 312
SECOND SURFACE
314
SECOND CHANNEL 316
FIRST TRANSPORT MEMBER
302
SECOND TRANSPORT MEMBER
304

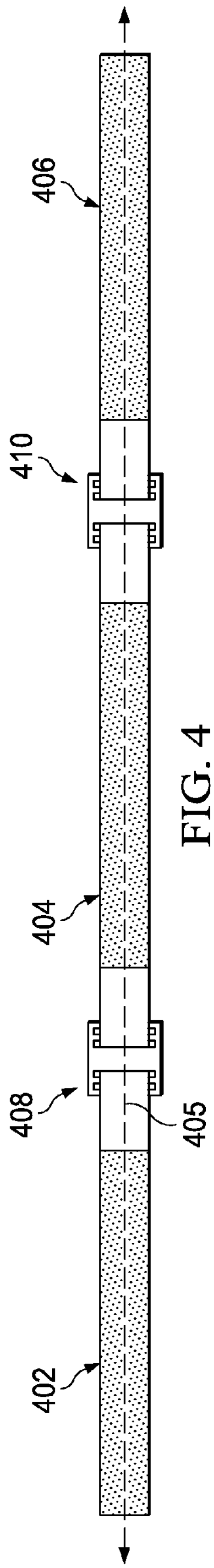

FIG. 4

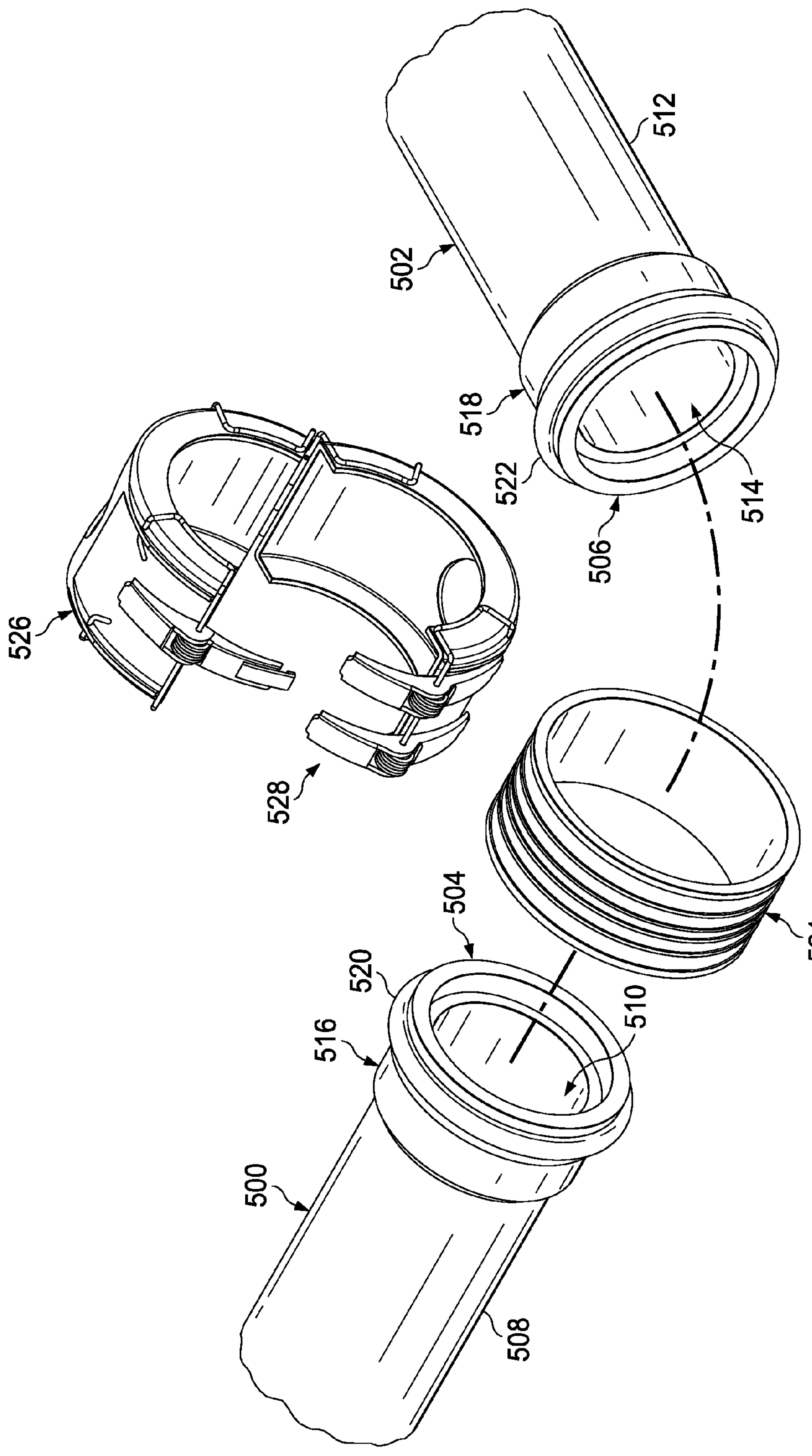

FIG. 5

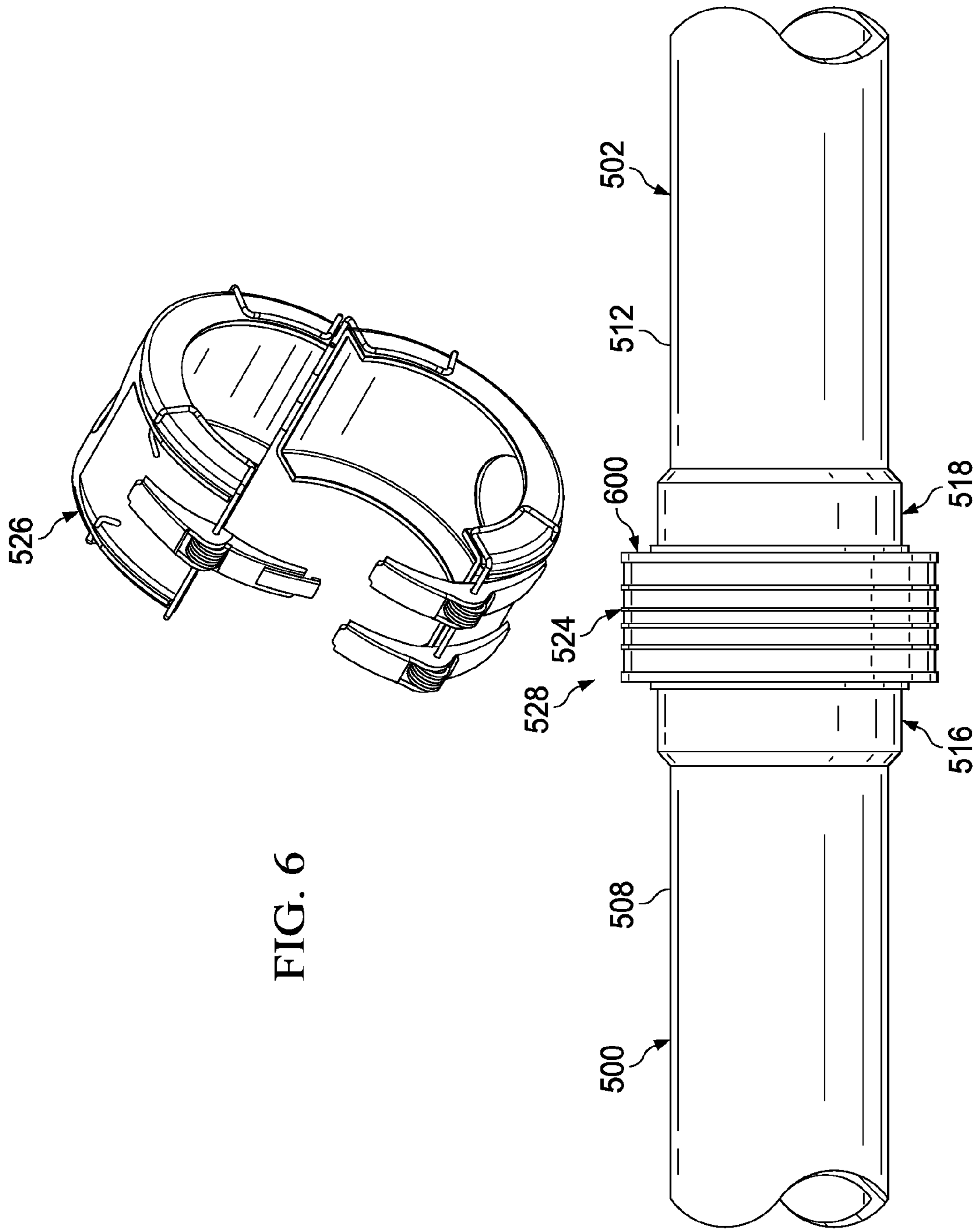

FIG. 6

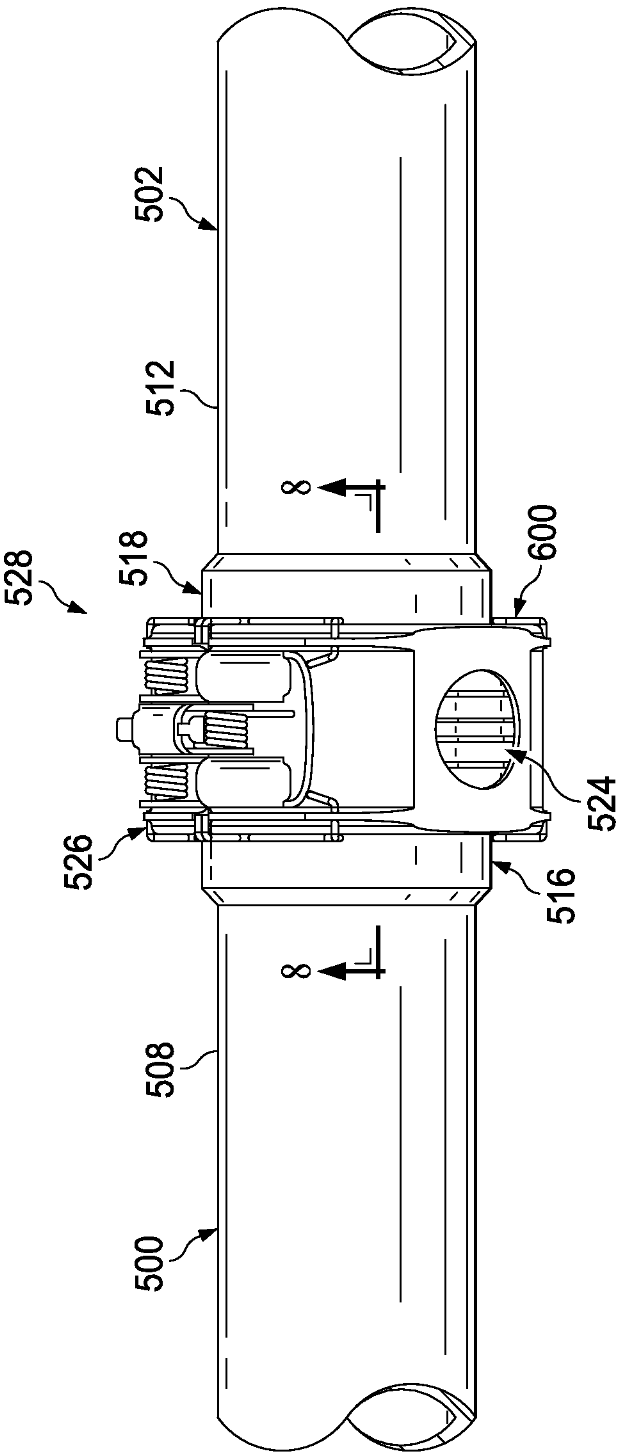

FIG. 7

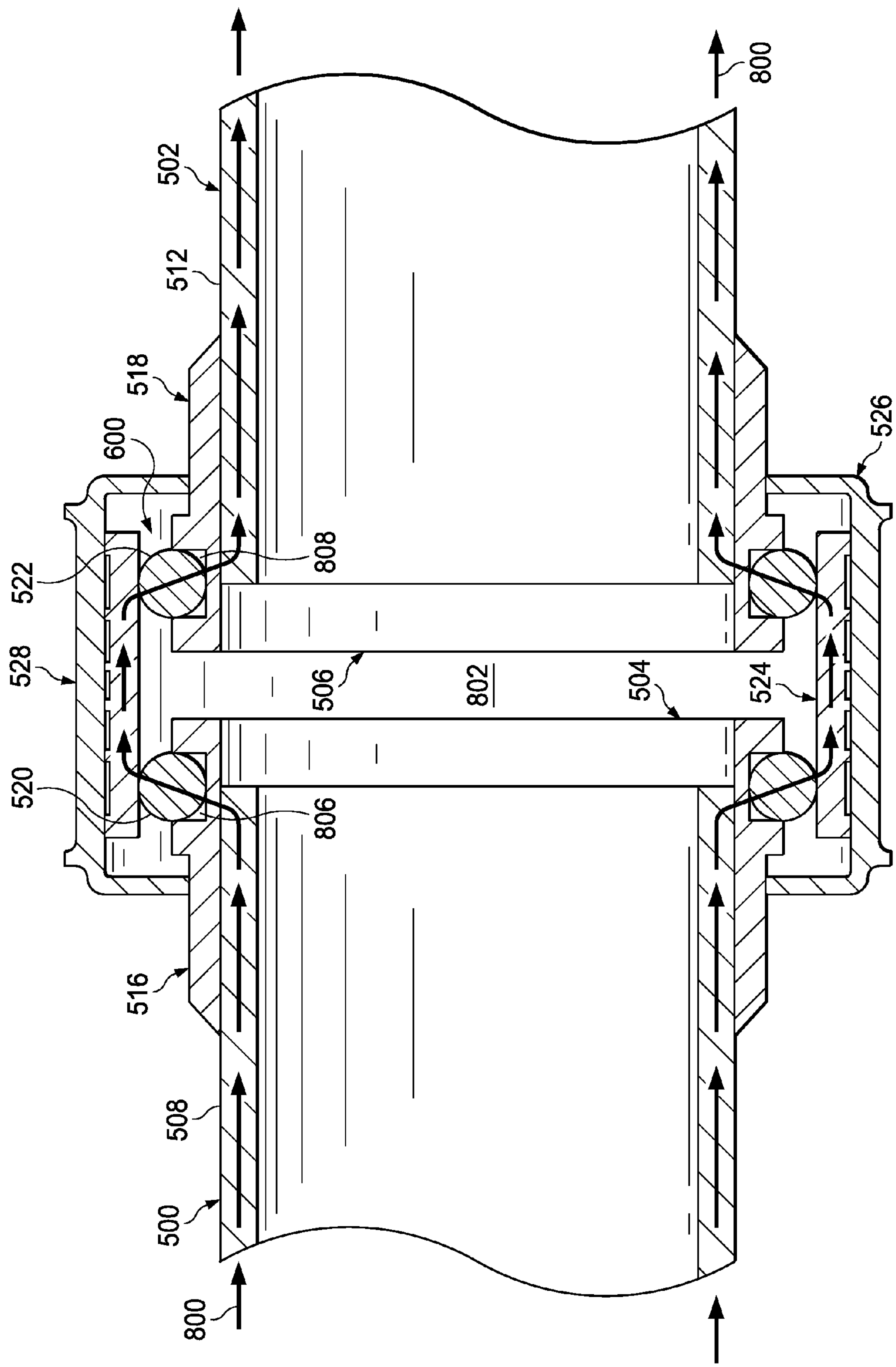
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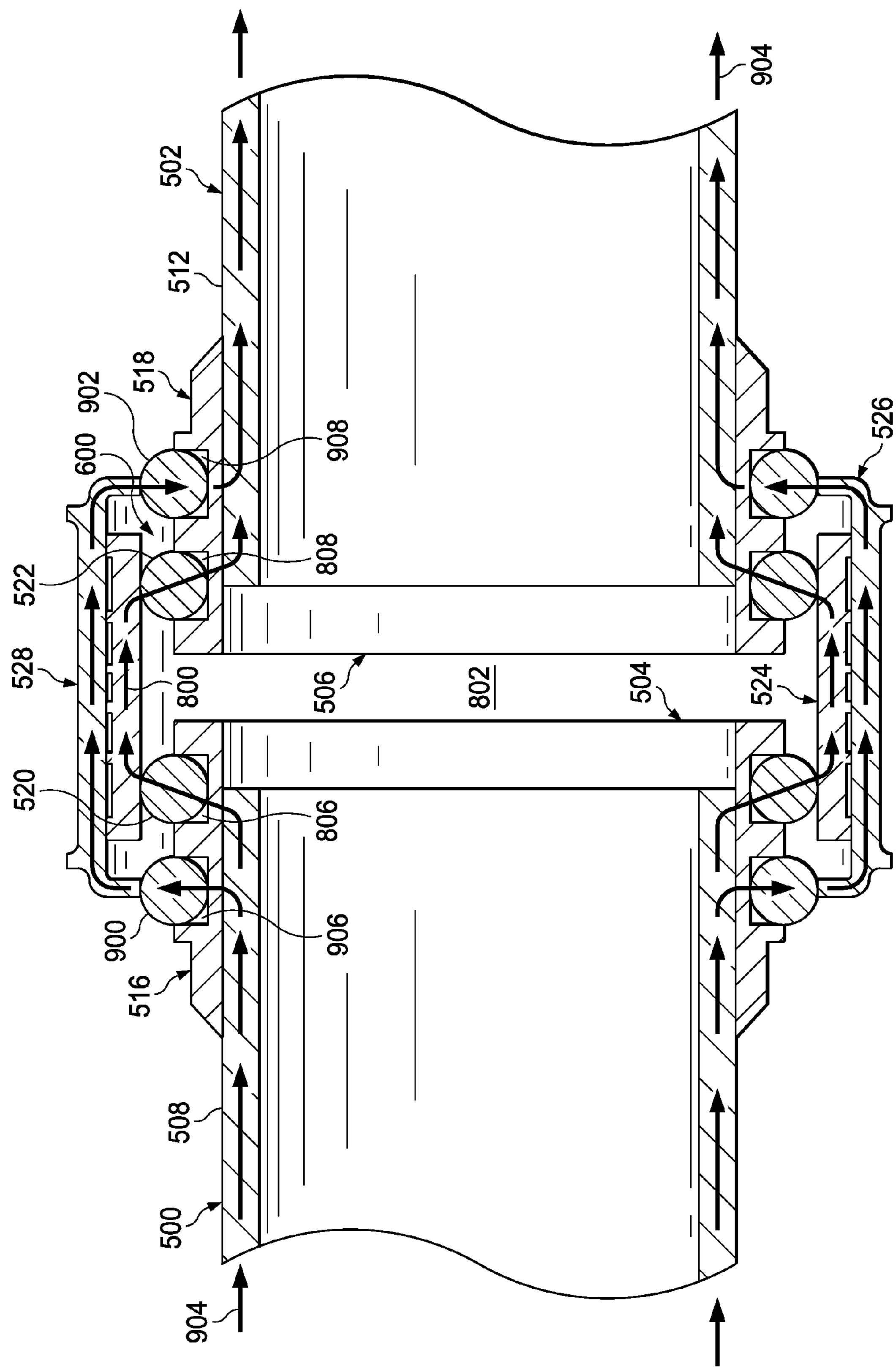
FIG. 8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904

FIG. 9

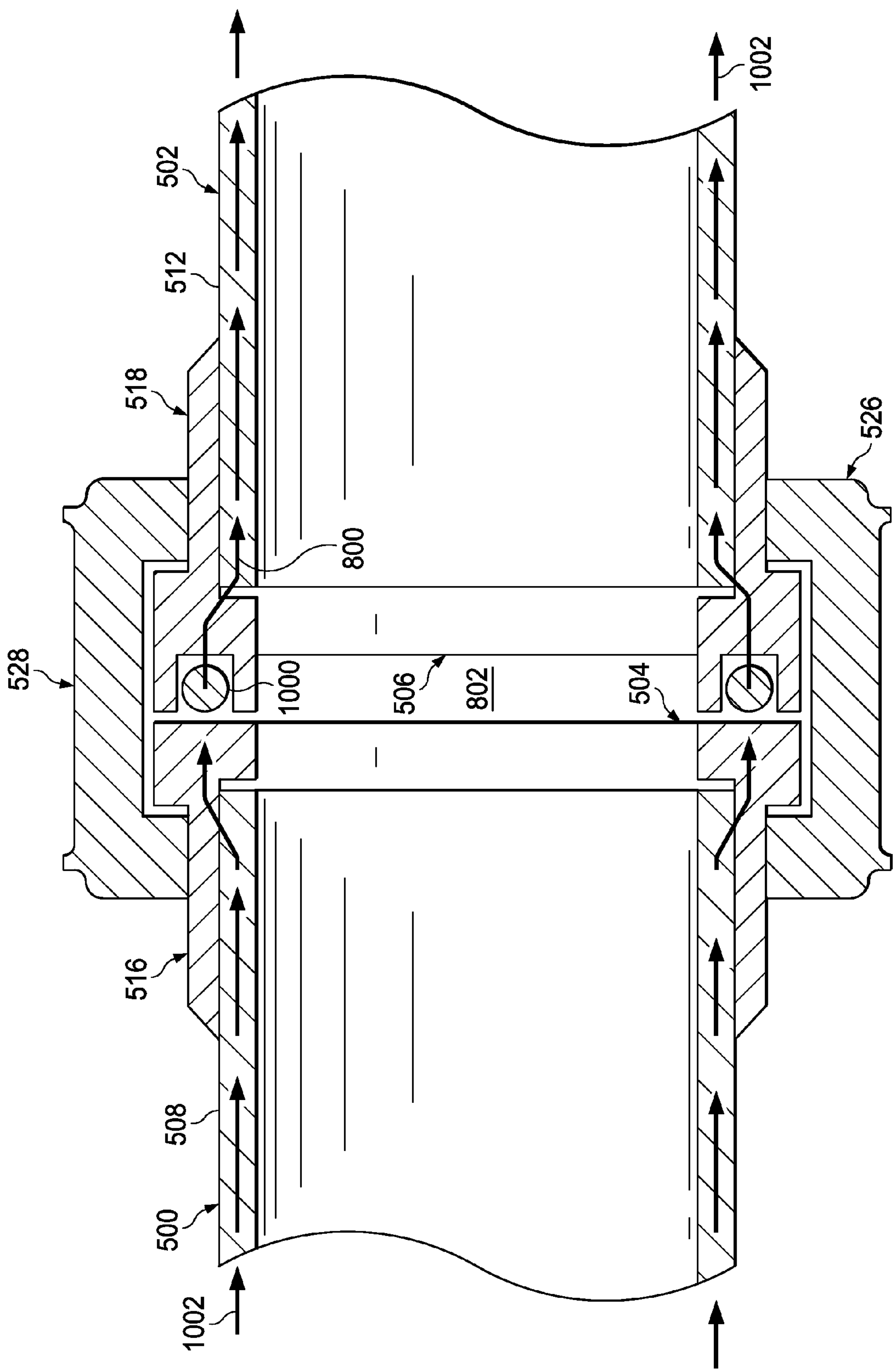

FIG. 10

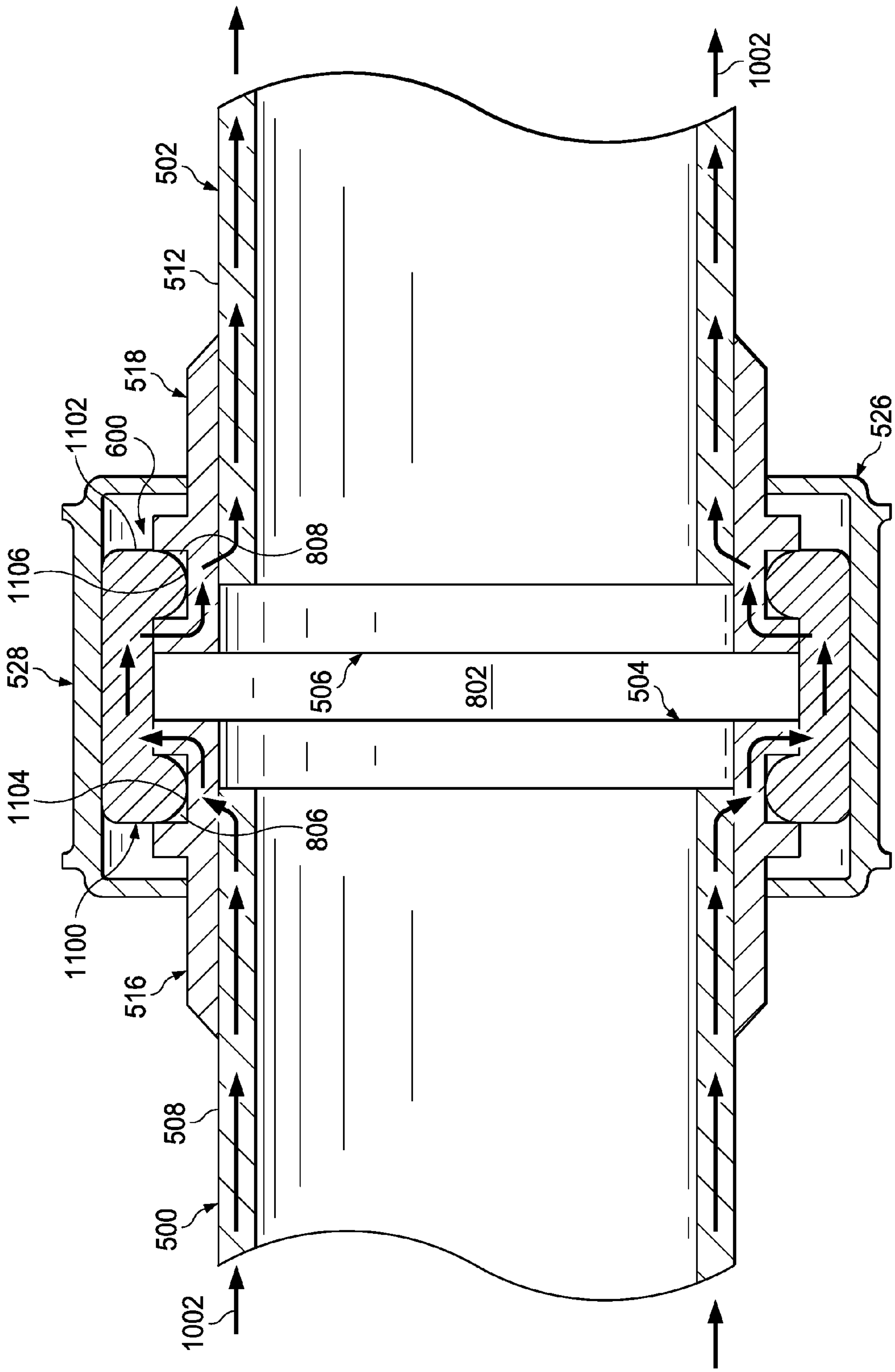
1002
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FIG. 11

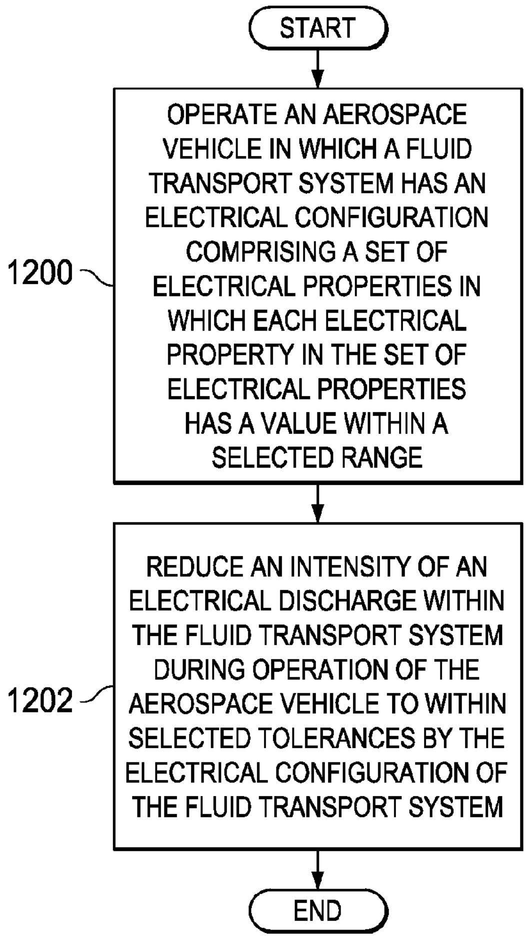

START
OPERATE AN AEROSPACE VEHICLE IN WHICH A FLUID TRANSPORT SYSTEM HAS AN ELECTRICAL CONFIGURATION COMPRISING A SET OF ELECTRICAL PROPERTIES IN WHICH EACH ELECTRICAL PROPERTY IN THE SET OF ELECTRICAL PROPERTIES HAS A VALUE WITHIN A SELECTED RANGE
1200
REDUCE AN INTENSITY OF AN ELECTRICAL DISCHARGE WITHIN THE FLUID TRANSPORT SYSTEM DURING OPERATION OF THE AEROSPACE VEHICLE TO WITHIN SELECTED TOLERANCES BY THE ELECTRICAL CONFIGURATION OF THE FLUID TRANSPORT SYSTEM
1202
END

FIG. 12

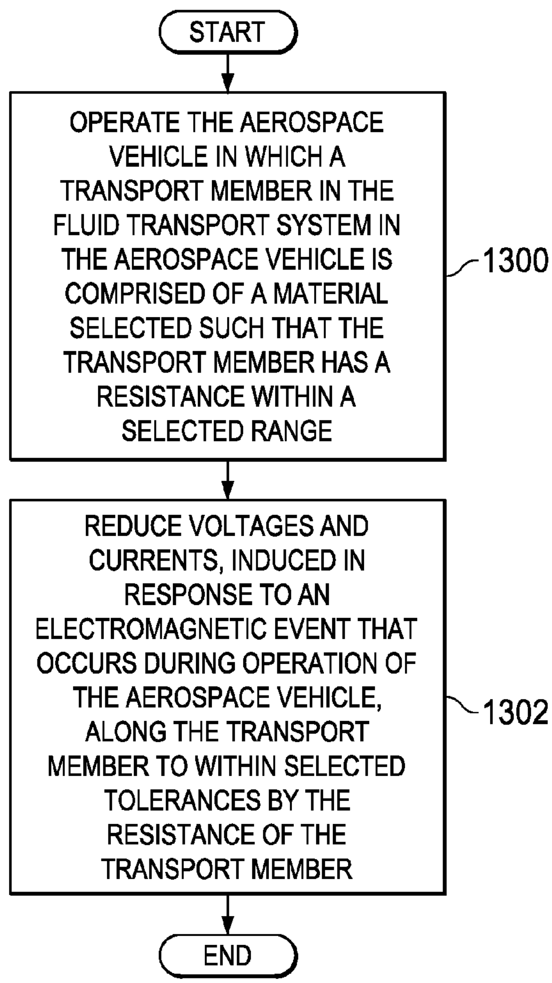

START
OPERATE THE AEROSPACE VEHICLE IN WHICH A TRANSPORT MEMBER IN THE FLUID TRANSPORT SYSTEM IN THE AEROSPACE VEHICLE IS COMPRISED OF A MATERIAL SELECTED SUCH THAT THE TRANSPORT MEMBER HAS A RESISTANCE WITHIN A SELECTED RANGE
1300
REDUCE VOLTAGES AND CURRENTS, INDUCED IN RESPONSE TO AN ELECTROMAGNETIC EVENT THAT OCCURS DURING OPERATION OF THE AEROSPACE VEHICLE, ALONG THE TRANSPORT MEMBER TO WITHIN SELECTED TOLERANCES BY THE RESISTANCE OF THE TRANSPORT MEMBER
1302
END

FIG. 13

FIG. 14

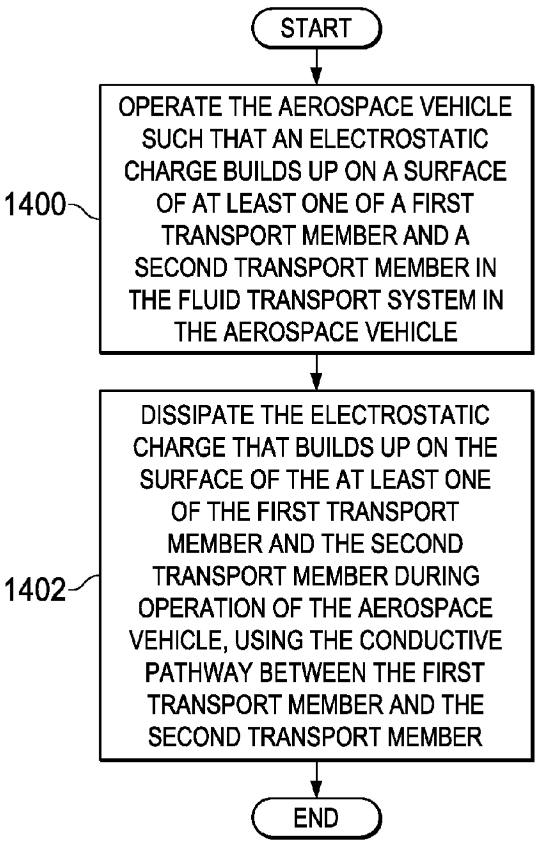


FIG. 15

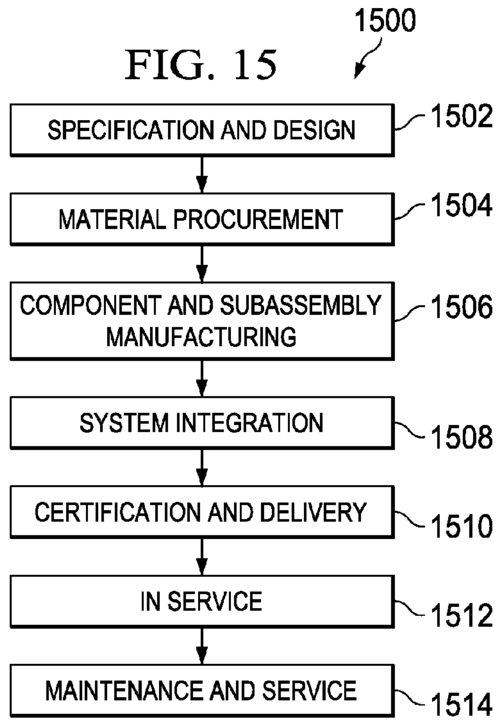
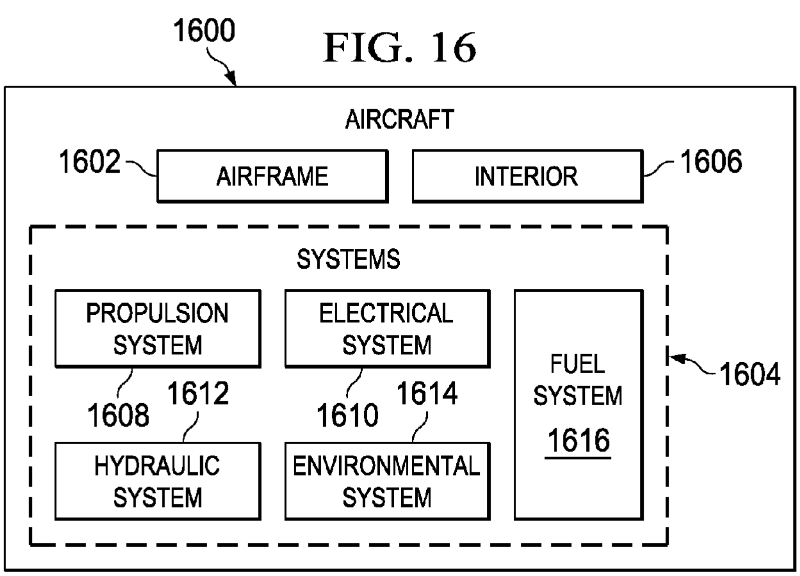


FIG. 16



FLUID TRANSPORT SYSTEM FOR PREVENTING ELECTRICAL DISCHARGE

This application is related to, and claims the benefit of priority of, the following provisional patent applications: Provisional Application for Patent Ser. No. 61/657,248, filing date Jun. 8, 2012, entitled "Conductive Coupling Assembly;" Provisional Application for Patent Ser. No. 61/669,299, filing date Jul. 9, 2012, entitled "Composite Tubes for a Fluid Transport System;" and Provisional Application for Patent Ser. No. 61/712,930, filing date Oct. 12, 2012, entitled "Fluid Transport System for Preventing Electrical Discharge;" all of which are incorporated herein by reference.

CROSS-REFERENCES TO RELATED CASES

This application is related to the following patent applications: entitled "Conductive Coupling Assembly," filing date Jan. 23, 2013, Ser. No. 13/747,732; and entitled "Composite Tubes for a Fluid Transport System," filing date Jan. 23, 2013, Ser. No. 13/747,761; filed of even date herewith, each assigned to the same assignee, and each incorporated herein by reference.

BACKGROUND INFORMATION

1. Field

The present disclosure relates generally to a fluid transport system and, in particular, to a fluid transport system configured to have a desired electrical configuration. Still more particularly, the present disclosure relates to a method and apparatus for limiting the flow of electric current, induced by an event such as lightning or an electrical fault, along a fluid transport system and allowing static dissipation along the fluid transport system.

2. Background

A fluid transport system typically includes tubes connected together for moving fluid through the tubes. As used herein, a "fluid" may comprise any number of liquids and/or gases. Fluid transport systems may be used to transport any number of fluids within vehicles, such as, for example, aircraft. A fluid transport system may include groups of tubes connected in series, in parallel, or a combination of the two. In some cases, these tubes may be coupled together using, for example, without limitation, coupling assemblies.

A fuel system is an example of one type of fluid transport system in an aircraft. Some currently available fuel systems comprise fuel tanks comprised of metal and/or composite materials, such as carbon fiber reinforced plastic (CFRP). When used in fuel tanks, fuel tubes comprised of plastic and/or metal materials may be prone to the buildup of electrostatic charge. The buildup of electrostatic charge on a fuel tube may be caused by a number of different factors including, but not limited to, the flow of fuel through and/or around the fuel tube.

When electrostatic charge builds up on a surface of a fuel tube, the fuel tube may be prone to electrical discharge of this electrostatic charge. This electrical discharge may be referred to as "static discharge." Static discharge may take the form of, for example, an electrical arc from the fuel tube to a nearby structure.

Further, when used in a fuel tank comprised of electrically resistive materials such as, for example, carbon reinforced plastic, fuel tubes comprised of plastic and/or metal materials may also be prone to voltages and currents induced by an electromagnetic event, such as lightning. In some situations, the induced voltages may lead to electrical discharge in the form of electrical sparking and/or arcing from the tubes to one or more nearby structures. Additionally, in some situations, the induced currents may lead to electrical discharge within the connections between tubes.

The voltage and currents induced by lightning may typically be small and within selected tolerances inside the fuel tanks of aircraft having wings comprised of metal materials, such as, for example, aluminum. However, the voltages and currents induced by lightning inside the fuel tanks of aircraft having wings comprised of non-metallic materials, such as, for example, carbon fiber reinforced plastic, may be greater and outside of selected tolerances. In particular, the higher electrical resistance of carbon fiber reinforced plastic as compared to aluminum may cause larger voltages and currents to be induced with respect to the tubes inside the fuel tanks.

Typically, with currently available aircraft, fuel transport systems use metal tubing to transport fuel within fuel tanks. In an aircraft comprised of carbon fiber reinforced plastic, the metal tubing may be prone to induced voltages that may cause undesired electrical discharges. Some currently available methods for reducing the level or intensity of an undesired electrical discharge may include inserting high resistance electrical isolators into the metal tubing. These isolators may be used to constrain the currents and voltages that may be induced by lightning, thereby reducing the level of any undesired electrical discharge that may occur.

However, the weight and expense needed to install metal systems having these isolators may be greater than desired. Part of the cost and expense to install such metal systems with isolators may be the need to protect the metal systems against arcing from the induced voltages remaining in the system after the installation of the isolators.

Additionally, an electrical discharge within a fuel system caused by the buildup of electrostatic charge and/or induced voltages and currents in response to an electromagnetic event such as lightning may present safety concerns. Therefore, it would be desirable to have a method and apparatus that takes into account at least some of the issues discussed above, as well as other possible issues.

SUMMARY

In one illustrative embodiment, a fluid transport system comprises a plurality of transport members and a number of connections connecting transport members in the plurality of transport members to each other. The plurality of transport members and the number of connections are comprised of materials selected such that an intensity of an electrical discharge that occurs within the fluid transport system is reduced to within selected tolerances.

In another illustrative embodiment, a fluid transport system having an electrical configuration is configured to reduce an intensity of an electrical discharge that occurs within the fluid transport system. The fluid transport system comprises a plurality of tubes and a number of coupling assemblies. A tube in the plurality of tubes is comprised of a composite material selected such that the tube has a resistance within a selected range configured to reduce voltages and currents, induced in response to an electromagnetic event, along the tube to within selected tolerances. The number of coupling assemblies is configured to couple tubes in the plurality of tubes to each other. A coupling assembly in the number of coupling assemblies comprises a first fitting associated with a first end of a first tube in the plurality of tubes, a second fitting associated with a second end of a second tube in the plurality of tubes, and a seal. The seal is configured for placement around the first fitting and the second fitting when the first end of the first

tube is positioned relative to the second end of the second tube. The seal is configured to seal an interface between the first end of the first tube and the second end of the second tube. The seal is further configured to provide a conductive pathway between the first tube and the second tube to allow electrostatic charge that builds up on at least one of the first tube and the second tube to be dissipated.

In yet another illustrative embodiment, a method for reducing an intensity of an electrical discharge that occurs within a fluid transport system in an aerospace vehicle is provided. The aerospace vehicle is operated. The fluid transport system in the aerospace vehicle is comprised of materials selected such that the fluid transport system has an electrical configuration. The intensity of the electrical discharge that occurs within the fluid transport system during operation of the aerospace vehicle is reduced to within selected tolerances by the electrical configuration of the fluid transport system.

The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives, and features thereof will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is an illustration of a fluid transport system in the form of a block diagram in accordance with an illustrative embodiment;

FIG. **2** is an illustration of a transport member in the form of a block diagram in accordance with an illustrative embodiment;

FIG. **3** is an illustration of a connection in the form of a block diagram in accordance with an illustrative embodiment;

FIG. **4** is an illustration of tubes configured for use in a fluid transport system in accordance with an illustrative embodiment;

FIG. **5** is an illustration of components for a coupling assembly in accordance with an illustrative embodiment;

FIG. **6** is an illustration of a partially-assembled coupling assembly in accordance with an illustrative embodiment;

FIG. **7** is an illustration of a fully-assembled coupling assembly in accordance with an illustrative embodiment;

FIG. **8** is an illustration of a cross-sectional view of a coupling assembly in accordance with an illustrative embodiment;

FIG. **9** is an illustration of a cross-sectional view of a different configuration for a coupling assembly in accordance with an illustrative embodiment;

FIG. **10** is an illustration of a cross-sectional view of another configuration for a coupling assembly in accordance with an illustrative embodiment;

FIG. **11** is an illustration of a cross-sectional view of a different configuration for a coupling assembly in accordance with an illustrative embodiment;

FIG. **12** is an illustration of a process for reducing an intensity of an electrical discharge within a fluid transport system in the form of a flowchart in accordance with an illustrative embodiment;

FIG. **13** is an illustration of a process for reducing the energy that can be supplied to an electrical discharge within a fluid transport system in the form of a flowchart in accordance with an illustrative embodiment;

FIG. **14** is an illustration of a process for dissipating electrostatic charge in the form of a flowchart in accordance with an illustrative embodiment;

FIG. **15** is an illustration of an aircraft manufacturing and service method in the form of a flowchart in accordance with an illustrative embodiment; and

FIG. **16** is an illustration of an aircraft in the form of a block diagram in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

The different illustrative embodiments recognize and take into account different considerations. For example, the different illustrative embodiments recognize and take into account that it may be desirable to have a fluid transport system configured to reduce the intensity of electrical discharge from components, such as, for example, tubes, within the fluid transport system.

The different illustrative embodiments recognize and take into account that tubes comprised of materials with high electrical resistance levels may be used in a fluid transport system to reduce the intensity of electrical discharge caused by voltages and currents induced in response to an electromagnetic event such as, for example, lightning. High levels of electrical resistance may include levels above, for example, about 100 kilohms per meter length of tube.

Materials with high levels of electrical resistance include, but are not limited to, nonmetallic fiber reinforced composite materials, carbon reinforced plastic materials, plastic materials, non-homogenous metallic materials, and/or other types of materials. The illustrative embodiments recognize and take into account that tubes comprised of any of these types of materials may limit the levels of voltages and currents induced in response to the occurrence of an electromagnetic event, thereby reducing the intensity of any electrical discharge caused by these induced voltages and/or currents.

For example, materials having high levels electrical resistance may limit the current induced along a tube in response to an electromagnetic event, such as lightning. With fuel tubes in a fuel system, limiting the flow of current along these fuel tubes may limit the voltages induced across the connections between these fuel tubes when the electrical resistance of these connections is lower than the electrical resistance through a specified length of fuel tube connected to the connection. The specified length, for example, may be 0.3 meters of tube. In this manner, electrical discharge in the form of electrical sparking and/or arcing may be reduced and/or prevented. Consequently, the illustrative embodiments recognize and take into account that an upper limit for resistivity or, equivalently, a lower limit for conductivity, may be selected for the materials used in the connections between fuel tubes to reduce electrical discharge across these connections and along the fuel tubes.

However, the illustrative embodiments recognize and take into account that in some cases, if a conductive material were to become dislodged from a connection between fuel tubes and form a bridge between a metal fuel tube and a structure within the fuel tank, the conductive material could short circuit this bridge and allow, for example, lightning to induce a flow of current or possibly a spark from the fuel tube to the structure. As a result, the illustrative embodiments recognize and take into account that the resistivity of the conductive material may require a lower limit for resistivity, or equivalently, an upper limit for conductivity.

However, the different illustrative embodiments recognize and take into account that in other cases, fuel tubes may be used in metallic fuel tanks in which lightning induced voltages and/or currents may be within selected tolerances. Consequently, the materials used in the connections between fuel tubes may only need to be selected to allow dissipation of electrostatic charge that has built up along these fuel tubes. Consequently, the illustrative embodiments recognize and take into account that only an upper limit for resistivity or, equivalently, a lower limit for conductivity, may need to be selected for the materials used in the connections between fuel tubes to reduce electrical discharge across these connections.

Further, the illustrative examples recognize and take into account that the possibility of a static discharge caused by the build-up of electrostatic charge may be reduced and/or prevented by grounding fuel tubes to a structure having a resistance that is sufficiently low to remove electrostatic charge from the fuel tubes at a rate faster than the electrostatic charge can build up on the fuel tubes such that a net charge on the fuel tubes within selected tolerances may be maintained. In particular, a net charge on the fuel tubes may be reduced to within selected tolerances. The different illustrative embodiments recognize and take into account that when fuel tubes are connected in series, electrostatic charge may be removed from the series of fuel tubes by using conductive pathways through the connections between the fuel tubes and then grounding the series to the structure.

Thus, the different illustrative embodiments provide a system and method for reducing an intensity of electrical discharge within a fluid transport system. In one illustrative embodiment, the fluid transport system is located within a vehicle, such as an aerospace vehicle. Further, the fluid transport system may be comprised of materials selected such that the fluid transport system has a selected electrical configuration. This electrical configuration for the fluid transport system may be selected such that electrical discharge that occurs within the fluid transport system during operation of the aerospace vehicle may be reduced to within selected tolerances.

Referring now to the figures and, in particular, with reference to FIG. **1**, an illustration of a fluid transport system in the form of a block diagram is depicted in accordance with an illustrative embodiment. Fluid transport system **100** is configured to transport materials within platform **104**.

The materials transported may include any number of liquid materials, gaseous materials, and/or solid materials. As one illustrative example, fluid transport system **100** may be used to transport fluid **102** within platform **104**. Fluid **102** may comprise any number of liquids and/or gases.

In one illustrative example, platform **104** takes the form of aerospace vehicle **106**. In this illustrative example, fluid transport system **100** may take the form of fuel system **105** configured to transport fluid **102** in the form of fuel **108** within aerospace vehicle **106**. Aerospace vehicle **106** may be selected from one of an aircraft, a helicopter, an unmanned aerial vehicle (UAV), a space shuttle, or some other suitable type of vehicle configured to travel in air and/or space. Of course, in other illustrative examples, platform **104** may take the form of a ground vehicle, a water vehicle, or some other suitable type of vehicle.

As depicted, fluid transport system **100** comprises plurality of transport members **110** and number of connections **112**. As used herein, a "plurality of" items means two or more items. Further, a "number of" items means one or more items. For example, plurality of transport members **110** means two or more transport members, while number of connections **112** means one or more connections.

As used herein, a "transport member," such as one of plurality of transport members **110**, may be any structural member having a channel through which materials may be moved. Depending on the implementation, a transport member in plurality of transport members **110** may take the form of, for example, a tube, a duct, a cylinder, a pipe, a pipeline, a conduit, or some other type of structure having a channel through which materials may flow. As one illustrative example, plurality of transport members **110** may take the form of plurality of tubes **111**.

Further, as used herein, a "connection," such as one of number of connections **112**, may be any type of permanent or removable physical connection between two or more transport members in plurality of transport members **110**. Depending on the implementation, a connection in number of connections **112** may comprise any number of components such as, for example, without limitation, fasteners, joint elements, screws, ferrules, rings, seals, adhesive bonds, and/or other types of components.

As one illustrative example, number of connections **112** may take the form of number of coupling assemblies **113**. Each coupling assembly in number of coupling assemblies **113** may be configured to couple a transport member in plurality of transport members **110** with another transport member in plurality of transport members **110**. In this manner, when plurality of transport members **110** takes the form of plurality of tubes **111**, number of coupling assemblies **113** may be used to couple tubes in plurality of tubes **111** to each other.

As used herein, a first component, such as a tube, "coupled" to a second component, such as another tube, means that the first component is connected to or fastened to the second component. This connection may be a direct connection or an indirect connection. For example, an end of one tube may be coupled to the end of another tube using a coupling assembly. With a direct connection, the end of the tube may come into contact with the end of the other tube when these two ends are coupled. With an indirect connection, the end of the tube and the end of the other tube may not contact each other when these two ends are coupled.

Of course, in other illustrative examples, number of connections **112** may take other forms. For example, transport members may be attached to each other using other methods, such as, for example, applying adhesives to permanently connect transport members or performing thermoplastic welding operations.

In these illustrative examples, fluid transport system **100** is configured such that fluid transport system **100** has selected electrical configuration **114**. Selected electrical configuration **114** may be comprised of set of electrical properties **116**, each having a value within a selected range. As used herein, a "set of" items means one or more items.

Set of electrical properties **116** may include, for example, resistance, resistivity, conductivity, and/or other types of electrical properties. Further, in some cases, any component that makes up fluid transport system **100** may be configured such that the component also has a set of electrical properties with values within selected ranges.

Selected electrical configuration **114** may be selected such that an intensity of electrical discharge that occurs within fluid transport system **100** during operation of aerospace vehicle **106** may be reduced to within selected tolerances. In particular, selected electrical configuration **114** may be selected such that voltages and currents, induced within fluid transport system **100** in response to an electromagnetic event such as lighting, may be constrained to within selected tolerances. Still further, selected electrical configuration **114** may be selected to allow dissipation of electrostatic charge that may build up along plurality of transport members **110** during operation of aerospace vehicle **106**.

Turning now to FIG. **2**, an illustration of a transport member in plurality of transport members **110** from FIG. **1** in the form of a block diagram is depicted in accordance with an illustrative embodiment. Transport member **200** in FIG. **2** is an example of one implementation for a transport member in plurality of transport members **110** in FIG. **1**. In one illustrative example, transport member **200** takes the form of tube **201**. Tube **201** may be an example of one implementation for a tube in plurality of tubes **111** in FIG. **1**.

As depicted, transport member **200** has first end **202** and second end **204**. Further, transport member **200** has outer surface **203** and inner surface **205**. Inner surface **205** may form channel **206** that extends along axis **215** through transport member **200** from first end **202** of transport member **200** to second end **204** of transport member **200**. Axis **215** may be a center axis that extends through transport member **200** from first end **202** of transport member **200** to second end **204** of transport member **200**. Fluid **102** from FIG. **1** may be carried within channel **206**.

In these illustrative examples, connection **218** may be an example of a connection in number of connections **112** that may be used to connect transport member **200** to another transport member in plurality of transport members **110** in FIG. **1**. As depicted, connection **218** may be used at either first end **202** of transport member **200** or second end **204** of transport member **200** to connect transport member **200** to another transport member.

In one illustrative example, connection **218** takes the form of coupling assembly **220**. Coupling assembly **220** may comprise any number of components such as, for example, without limitation, fasteners, joint elements, screws, ferrules, rings, seals, and/or other types of components.

In these illustrative examples, transport member **200** may be comprised of material **207**. Material **207** may be selected such that transport member **200** has electrical configuration **210**. Electrical configuration **210** may comprise set of electrical properties **212**, each having a value within a selected range. In one illustrative example, set of electrical properties **212** includes resistance **214**. Resistance **214** may be electrical resistance in these examples.

As used herein, the "resistance" of an item, such as transport member **200**, is the opposition of the item to the flow of electric current through the item. In this manner, resistance **214** of transport member **200** may be the opposition of transport member **200** to the flow of electric current through transport member **200**.

Material **207** may be selected such that resistance **214** is within selected range **216**. Selected range **216** for resistance **214** may be selected such that resistance **214** is sufficiently high to limit the voltages and currents, induced along transport member **200** in response to an electromagnetic event, to within selected tolerances. The electromagnetic event may be, for example, a lightning strike, a short circuit, an overloaded circuit, an electrical field, or some other type of electromagnetic event.

In particular, material **207** may be selected such that the induced voltages and currents may be limited to levels at or below the level at which an undesired electrical discharge may be formed. The undesired electrical discharge may be, for example, an arc between transport member **200** and a structure and/or a spark in connection **218** having at least one property outside of selected tolerances.

In one illustrative example, when transport member **200** is installed within a particular specified electromagnetic environment, selected range **216** for resistance **214** of transport member **200** may be selected such that the per unit length resistance **214** of transport member **200** is at or above about 100 kilohms per meter (kΩ/m). For example, when transport member **200** is installed in a fuel tank of an aircraft comprised of carbon fiber reinforced plastic, the specified electromagnetic environment may be a specified lightning environment.

Further, when transport member **200** is configured to allow static dissipation and reduce and/or prevent the build-up of electrostatic charge, selected range **216** for resistance **214** of transport member **200** may be selected such that the per unit length resistance **214** of transport member **200** is at or below about 100 megohms per meter (MΩ/m).

Material **207** may take a number of different forms. Material **207** may comprise, for example, without limitation, non-metallic fiber reinforced composite materials, plastic materials, and/or other suitable types of non-homogeneous metallic materials. In one illustrative example, material **207** takes the form of composite material **208** comprised of any number of non-metallic materials. When comprised of composite material **208**, transport member **200** may be referred to as a composite transport member. In this manner, tube **201** may be referred to as a composite tube.

In this manner, selected range **216** may include levels of resistance **214** sufficiently low to provide static dissipation. Further, selected range **216** may include levels of resistance **214** sufficiently high to limit the voltages and currents induced along transport member **200** in response to an electromagnetic event.

Further, in these illustrative examples, resistance **214** of transport member **200** may vary along axis **215**. However, composite material **208** may be selected such that resistance **214** does not vary outside of selected tolerances. For example, transport member **200** may be formed using composite material **208** selected such that resistance **214** of transport member **200** may vary only by less than a selected percentage over the length of the transport member and time with respect to axis **215**. This selected percentage may be between about 20 percent and about 40 percent in one illustrative example.

In one illustrative example, each transport member in plurality of transport members **110** in FIG. **1** may be implemented in a manner similar to transport member **200**. Resistance within selected range **216** may be distributed evenly over individual intervals of length of tubing installed in fluid transport system **100** in FIG. **1**.

When fluid transport system **100** takes the form of fuel system **105** in FIG. **1** located in a fuel tank, the distributed high electrical resistance may keep the electromagnetic fields inside the fuel tank induced by lightning from being concentrated, thereby reducing the voltages and currents induced along the tubing. The per unit length resistance with respect to particular lengths of tubing in fuel system **105** may be different between different length intervals, but evenly distributed within these length intervals.

With reference now to FIG. **3**, an illustration of a connection in number of connections **112** from FIG. **1** in the form of a block diagram is depicted in accordance with an illustrative embodiment. Connection **300** is an example of one implementation for a connection in number of connections **112** in FIG. **1**. Connection **300** may take the form of coupling assembly **301**. Coupling assembly **301** may be an example of one implementation for a coupling assembly in number of coupling assemblies **113** in FIG. **1**.

In some cases, connection **300** may be used to implement connection **218** in FIG. **2**. For example, coupling assembly **301** may be used to implement coupling assembly **220** in FIG. **2**.

As depicted, connection **300** is used to couple first transport member **302** with second transport member **304**. In particular, first end **306** of first transport member **302** is coupled to second end **308** of second transport member **304** using connection **300**. First transport member **302** has first surface **310** and first channel **312**. Second transport member **304** has second surface **314** and second channel **316**.

First channel **312** and second channel **316** may be configured to allow different types of materials to flow through first transport member **302** and second transport member **304**, respectively. These materials may include any number of liquid materials, gaseous materials, and/or solid materials. In one illustrative example, first transport member **302** and second transport member **304** may be a first fuel transport member and a second fuel transport member, respectively, through which fuel **108** from FIG. **1** is allowed to flow.

When first end **306** of first transport member **302** is coupled to second end **308** of second transport member **304**, material may flow between first channel **312** within first transport member **302** and second channel **316** within second transport member **304**. In this manner, first channel **312** and second channel **316** may form a channel that extends through both first transport member **302** and second transport member **304** when first transport member **302** and second transport member **304** are coupled to each other.

In these illustrative examples, connection **300** may be configured such that the electrical resistance across connection **300** is less than the electrical resistance through a specified length of first transport member **302** and through a specified length of second transport member **304**. This specified length may be, for example, without limitation, about one foot (ft) or about one third of a meter (m) when connection **300** is implemented within a fuel tank in an aircraft comprised of carbon fiber reinforced plastic. In particular, this specified length may apply when first transport member **302**, second transport member **304**, and connection **300** are comprised of similarly non-metallic highly electrically resistive materials.

In this manner, each of the individual components that make up connection **300** may be configured such that the electrical resistance across connection **300** is less than the electrical resistance through the specified length of first transport member **302** and through the specified length of second transport member **304**. The components that make up connection **300** may be comprised of any number of materials including, but not limited to, metal, plastic, a composite material, and/or other types of materials.

If components having an electrical resistance outside of the selected range are used in forming connection **300**, the size and/or placement of these pieces relative to first transport member **302** and second transport member **304** may have restrictions. As one illustrative example, if a piece of metal having an electrical resistance outside of the selected range is used, the piece may need to have electrical ground paths to and through first transport member **302**, second transport member **304**, and/or other transport members. This type of grounding may allow static dissipation from tube to tube through the piece of metal and from the piece of metal to ground through one of the tubes.

In one illustrative example, connection **300** may include first fitting **318**, second fitting **320**, seal **322**, and cover **324**. First fitting **318** and second fitting **320** are associated with first end **306** of first transport member **302** and second end **308** of second transport member **304**, respectively. In particular, first fitting **318** is associated with first surface **310** of first transport member **302** at first end **306** of first transport member **302**. Further, second fitting **320** is associated with second surface **314** of second transport member **304** at second end **308** of second transport member **304**.

When one component is "associated" with another component, as used herein, this association is a physical association. For example, a first component, such as first fitting **318**, may be considered to be associated with a second component, such as first transport member **302**, by being secured to the second component, bonded to the second component, mounted to the second component, welded to the second component, fastened to the second component, and/or connected to the second component in some other suitable manner. The first component also may be connected to the second component using a third component. Additionally, the first component may also be considered to be associated with the second component by being formed as part of and/or an extension of the second component.

In one illustrative example, first fitting **318** takes the form of first ferrule **326**, and second fitting **320** takes the form of second ferrule **328**. As used herein, a "ferrule," such as first ferrule **326** and second ferrule **328**, is a ring-type object used for fastening, joining, and/or reinforcement. A ferrule may take the form of a ring, a bracelet, a sleeve, a circular clamp, a spike, a band, or some other suitable type of object.

First ferrule **326** is placed around first surface **310** of first transport member **302** at first end **306** of first transport member **302**. Second ferrule **328** is placed around second surface **314** of second transport member **304** at second end **308** of second transport member **304**.

In these illustrative examples, seal **322** is configured for placement around first fitting **318** and second fitting **320** when first end **306** of first transport member **302** is positioned relative to second end **308** of second transport member **304**. For example, seal **322** may be placed around first end **306** and second end **308** when first end **306** is positioned against second end **308**.

Seal **322** is configured to seal interface **330** formed between first end **306** of first transport member **302** and second end **308** of second transport member **304** when first end **306** of first transport member **302** and second end **308** of second transport member **304** are positioned relative to each other. Sealing interface **330** means reducing the possibility of material flowing into and/or out of the channel formed by first channel **312** within first transport member **302** and second channel **316** within second transport member **304** at interface **330** when first transport member **302** is coupled to second transport member **304**.

In some illustrative examples, seal **322** may be configured such that connection **300** has electrical configuration **329**. Electrical configuration **329** comprises set of electrical properties **333**, each having a value within a selected range. Electrical configuration **329** for connection **300** may be selected such that connection **300** forms conductive pathway **331** between first transport member **302** and second transport member **304**.

Conductive pathway **331** may be a pathway that allows an electrical current to flow between first transport member **302** and second transport member **304**. In other words, conductive pathway **331** allows an electrical current to be conducted between first transport member **302** and second transport member **304**. For example, electrical currents flowing through first surface **310** of first transport member **302** may be conducted to second surface **314** of second transport member **304** when conductive pathway **331** is present. In this manner, electrostatic charge may be dissipated using conductive pathway **331** formed by connection **300**.

In an illustrative example, at least a portion of seal **322** comprises viscoelastic material **332**. Viscoelastic material **332** is a material that comprises both viscous and elastic properties. A viscous material is a material that is resistant to being deformed by shear forces. An elastic material is a material that can return to its original shape after the stress that caused deformation of the material is no longer applied.

In these illustrative examples, viscoelastic material **332** is nonmetallic. Further, viscoelastic material **332** may be selected such that viscoelastic material **332** has a level of conductivity **335** within selected range **334** in these examples.

Selected range **334** may be selected such that conductive pathway **331** is formed between first transport member **302** and second transport member **304** when first transport member **302** is coupled to second transport member **304** using connection **300**. In this illustrative example, selected range **334** may include levels of conductivity sufficiently high to allow electrostatic charge that builds up on first transport member **302** and/or second transport member **304** to be dissipated through seal **322**.

However, in some cases, selected range **334** may also include levels of conductivity sufficiently low to reduce voltages and currents, induced in response to an electromagnetic event, such as, for example, lightning, along first transport member **302** and/or second transport member **304**.

For example, selected range **334** may be between about 1×10^{-4} Siemens/centimeters (S/cm) and about 1×10^{-9} Siemens/centimeters (S/cm). Of course, in other illustrative examples, selected range **334** may be a particular level of conductivity between about 1×10^{-4} Siemens/centimeters and about 1×10^{-9} Siemens/centimeters. Of course, in other illustrative examples, the upper limit and/or lower limit for selected range **334** may be different, depending on the particular implementation for seal **322**.

Selected range **334** of conductivity **335** may also be the range selected for the conductivity of other components within connection **300**, first transport member **302**, and/or second transport member **304**. Further, first transport member **302**, second transport member **304**, first fitting **318**, second fitting **320**, seal **322**, and cover **324** may together have a level of conductivity that is within selected range **334**.

Conductivity is related to resistivity. The resistivity of an item is the ability of that item to prevent an electrical current from being conducted through the item. In particular, conductivity is the reciprocal of resistivity. As the conductivity of an item increases, the resistivity of the item decreases. Similarly, as the conductivity of an item decreases, the resistivity of the item increases. Selected range **334** for conductivity **335** corresponds to a range for resistivity between about 1×10^{4} ohms-centimeters (Ω-cm) and about 1×10^{9} ohms-centimeters (Ω-cm).

Viscoelastic material **332** may be selected from any number of materials configured to provide a level of conductivity **335** within selected range **334**. For example, viscoelastic material **332** may comprise at least one of a conductive elastomer, a conductive rubber, a conductive silicone material, and other suitable types of materials. An elastomer is a polymer that is viscoelastic.

As used herein, the phrase "at least one of," when used with a list of items, means different combinations of one or more of the listed items may be used and only one of each item in the list may be needed. For example, "at least one of item A, item B, and item C" may include, without limitation, item A or item A and item B. This example also may include item A, item B, and item C, or item B and item C. In other examples, "at least one of" may be, for example, without limitation, two of item A, one of item B, and 30 of item C; four of item B and seven of item C; or some other suitable combination.

In these illustrative examples, seal **322** comprises first gasket **336**, second gasket **338**, and sleeve **340**. As used herein, a "gasket," such as first gasket **336** and second gasket **338**, is a mechanical seal. In one illustrative example, first gasket **336** takes the form of first O-ring **342**, and second gasket **338** takes the form of second O-ring **344**. As used herein, an "O-ring," such as first O-ring **342** and second O-ring **344**, is a mechanical gasket in the shape of a torus. Further, an O-ring has a loop-type shape.

Of course, in other illustrative examples, first gasket **336** and second gasket **338** may take some other suitable form. For example, in some cases, first gasket **336** and second gasket **338** may be configured such that a cross-section of these gaskets has a triangular shape, a square shape, a rectangular shape, an oval shape, or some other suitable type of shape.

First O-ring **342** and second O-ring **344** are configured to be received by first fitting **318** and second fitting **320**, respectively. As one illustrative example, first O-ring **342** may fit into a groove around first fitting **318**, and second O-ring **344** may fit into a groove around second fitting **320**.

Sleeve **340** is then placed around first O-ring **342** and second O-ring **344** to apply pressure to first O-ring **342** and second O-ring **344**. This pressure compresses first O-ring **342** and second O-ring **344** and causes these O-rings to seal interface **330** between first end **306** of first transport member **302** and second end **308** of second transport member **304**.

Additionally, in some illustrative examples, cover **324** may be placed over seal **322**, at least a portion of first fitting **318**, and at least a portion of second fitting **320**. Cover **324** may be used to cover seal **322** and hold seal **322** in place. In one illustrative example, cover **324** takes the form of clamshell device **346**.

When interface **330** has been sealed using seal **322**, conductive pathway **331** is formed between first transport member **302** and second transport member **304**. As one illustrative example, first O-ring **342** and second O-ring **344** may be comprised of viscoelastic material **332** having a level of conductivity within selected range **334**. Further, each of first fitting **318**, second fitting **320**, and sleeve **340** may be comprised of a nonmetallic material having a level of conductivity within selected range **334**.

In this illustrative example, conductive pathway **331** may be formed through first transport member **302**, through first fitting **318**, through first O-ring **342**, through sleeve **340**, through second O-ring **344**, through second fitting **320**, and through second transport member **304**. When conductive pathway **331** is formed, an electrical current may flow in one of a first direction and a second direction.

The first direction may be from first transport member **302**, through first fitting **318**, through first O-ring **342**, through sleeve **340**, through second O-ring **344**, through second fitting **320**, and to second transport member **304**. The second direction may be from second transport member **304**, through second fitting **320**, through second O-ring **344**, through sleeve **340**, through first O-ring **342**, through first fitting **318**, and to first transport member **302**.

In this manner, electrical currents induced by electrostatic charge that builds up on first surface **310** of first transport member **302** and/or second surface **314** of second transport member **304** may be dissipated using conductive pathway **331**. In particular, with connection **300** coupling first transport member **302** and second transport member **304**, first transport member **302** and second transport member **304** may be considered grounded to each other.

In other words, an electrical current flowing into first transport member **302** may flow into second transport member **304** through coupling assembly **301** without interruption and without the level of the electrical current changing outside of selected tolerances. Similarly, an electrical current flowing into second transport member **304** may flow into first transport member **302** through coupling assembly **301** without interruption and without the level of the electrical current changing outside of selected tolerances.

In some cases, the electrical current traveling along conductive pathway **331** may be electrical current induced in response to an electromagnetic event such as, for example, a lightning strike. Selected range **334** of conductivity **335** may be selected such that the voltage drop across first O-ring **342** and the voltage drop across second O-ring **344** when this type of electrical current travels through first O-ring **342** and second O-ring **344**, respectively, is reduced to within selected tolerances.

In these illustrative examples, first transport member **302** and second transport member **304** may be fuel tubes in, for example, fuel system **105** in aerospace vehicle **106** in FIG. **1**. In some cases, fuel system **105** may be configured such that fuel system **105** has an overall level of conductivity within selected range **334**. Different portions of fuel system **105** may have different levels of conductivity and different ranges which apply to different portions of the fuel system. Some portions of the system may not be required to be within the range of conductivity specified. The one or more levels of conductivity within selected range **334** may be lower than the levels of conductivity for other portions of aerospace vehicle **106**. For example, fuel system **105** may have a level of conductivity between about 1×10^{-4} Siemens/centimeters and about 1×10^{-9} Siemens/centimeters. However, one or more other portions of aerospace vehicle **106** may have a level of conductivity above about 1×10^{-4} Siemens/centimeters.

In this manner, fluid transport system **100** in FIG. **1** having plurality of transport members **110**, each implemented in a manner similar to transport member **200** in FIG. **2**, and number of connections **112**, each implemented in a manner similar to connection **300** in FIG. **3**, may be configured to reduce electrical discharge within fluid transport system **100**. Plurality of transport members **110**, interconnected within fluid transport system **100** may have high electrical resistance levels substantially evenly distributed throughout this interconnected system of tubing.

In particular, the voltages and currents induced by lightning may be reduced and/or limited such that the energy imparted to the electrical discharge may be reduced. In this manner, the undesired effects of electrical discharge within fluid transport system **100** may be reduced and/or prevented. In particular, the overall energy supplied to the electrical discharge may be constrained to within selected tolerances.

In some cases, when implementing fluid transport system **100** comprising an interconnected network of high electrical resistance transport members, such as plurality of transport members **110**, the network of transport members may need to be grounded to structure at one or more points for the purposes of removing electrostatic charge build-up and constraining the lightning-induced voltages to the transport members. The transport members also may need to be grounded at the penetrations of an enclosure encompassing an electrically shielded volume in which fluid transport system **100** is installed, such as a fuel tank, in order to reduce the possibility of a portion of an external electromagnetic environment such as lightning or an electrical fault, entering the volume.

Grounds made to structure for the purpose of removing electrical charge to prevent electrostatic charge from building up along the transport members may be located at one or more places in fluid transport system **100** as a means to ensure that an electrical path exists though fluid transport system **100** from any point in fluid transport system **100** to structure or ground with a sufficiently low resistance to dissipate the electrostatic charge at a fast enough rate to prevent static charge build up at the point. In an electrostatic charging environment such as a fuel tank on an aircraft, an acceptable electrical resistance for providing the capability to dissipate electrostatic charge from a point on a tube though a path to structure or ground may be a value at or below about 100 megohms (MΩ).

In such case, grounds made for this purpose need only assure that this overall ground path resistance is accomplished. As such, a static ground resistance may be a value up to about 100 megohms (MΩ) in the limiting case, but in the usual case a value up to about 10 MΩ.

Grounds made to structure for the purpose of constraining the lightning induced voltages in the network of transport members in fluid transport system **100** may be located at one or more places in fluid transport system **100** as a means to ensure that the induced voltage from transport member to transport member and from transport member to structure at any point in fluid transport system **100** is less than a selected threshold. Grounds made to structure on the perimeter of a fuel tank for the purpose of shielding the fuel tank may be located at one or more places in the perimeter to prevent undesired voltages and currents from penetrating the fuel tank by means of conductive members to which said voltages and currents are induced by an external environment such as lightning outside the tank.

The illustrations of fluid transport system **100** in FIG. **1**, transport member **200** in FIG. **2**, and connection **300** in FIG. **3** are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be optional. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

In some illustrative examples, transport member **200** may have additional features not depicted in FIG. **2**. For example, without limitation, one or more structural features may extend into channel **206** from inner surface **205** of transport member **200**. These structural features may need to be taken into account when measuring resistance **214** for transport member **200**.

In other illustrative examples, seal **322** may comprise only gasket **352**. Gasket **352** is configured to be placed around first fitting **318** and second fitting **320**. Gasket **352** may have a shape configured for placement around first fitting **318** and second fitting **320**. For example, gasket **352** may have a first end that fits into a groove around first fitting **318** and a second end that fits into a groove around second fitting **320** when first end **306** of first transport member **302** is positioned relative to second end **308** of second transport member **304**. Further, gasket **352** may comprise viscoelastic material **332** having a level of conductivity within selected range **334**.

With this type of configuration for seal **322** in connection **300**, cover **324** is used to compress gasket **352** to seal interface **330** between first end **306** of first transport member **302** and second end **308** of second transport member **304**, instead of sleeve **340**. Further, with this configuration for seal **322**, conductive pathway **331** is formed through first transport member **302**, through first fitting **318**, through gasket **352**, through second fitting **320**, and through second transport member **304**.

In still other illustrative examples, seal **322** may include one or more gaskets in addition to first gasket **336** and second gasket **338**. For example, seal **322** may also include a third O-ring configured for placement around first fitting **318** and a fourth O-ring configured for placement around second fitting **320**.

These additional O-rings may be positioned such that cover **324** compresses the third O-ring and the fourth O-ring instead of sleeve **340**. Further, the third O-ring and the fourth O-ring provide an additional conductive pathway. This additional conductive pathway is through first transport member **302**, through first fitting **318**, through the third O-ring, through cover **324**, through the fourth O-ring, through second fitting **320**, and through second transport member **304**.

In some illustrative examples, first fitting **318** and/or second fitting **320** may not be considered part of connection **300**. For example, when first fitting **318** and second fitting **320** are part of first transport member **302** and second transport member **304**, respectively, these fittings may be considered separate from connection **300**. In other illustrative examples, cover **324** may not be considered part of connection **300**. For example, in some cases, connection **300** may include only seal **322**.

With reference now to FIG. **4**, an illustration of tubes configured for use in a fluid transport system is depicted in accordance with an illustrative embodiment. In FIG. **4**, tube **402**, tube **404**, and tube **406** may be configured for use in a fluid transport system, such as, for example, fluid transport system **100** in FIG. **1**. In particular, tube **402**, tube **404**, and tube **406** are examples of implementations of tubes in plurality of tubes **111** in FIG. **1**. Further, each of tube **402**, tube **404**, and tube **406** may be implemented in a manner similar to tube **201** in FIG. **2**.

In this illustrative example, tube **402**, tube **404**, and tube **406** are comprised of non-metallic composite materials and configured to have a resistance within a selected range. This selected range may be between about 100 kilohms per meter to about 100 megohms per meter along axis **405** through tube **402**, tube **404**, and tube **406**. With each of tube **402**, tube **404**, and tube **406** having a resistance within the selected range with respect to axis **405**, the flow of an electric current, induced in response to an electromagnetic event around these tubes, though these tubes may be limited to within selected tolerances. Axis **405** is a center axis for tube **402**, tube **404**, and tube **406**.

The illustration of tube **402**, tube **404**, and tube **406** in FIG. **4** are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. For example, in some cases, these tubes may be connected using other types of coupling assemblies other than coupling assembly **408** and coupling assembly **410**.

With reference now to FIGS. **5-11**, illustrations of different configurations for a coupling assembly are depicted in accordance with different illustrative embodiments. The components depicted in FIGS. **5-11** may be illustrative examples of how components shown in block form in FIG. **3** may be implemented as physical structures. The different components shown in FIGS. **5-11** may be combined with components in FIG. **3**, used with components in FIG. **3**, or a combination of the two.

Turning now to FIG. **5**, an illustration of components for a coupling assembly is depicted in accordance with an illustrative embodiment. In this illustrative example, components for a coupling assembly, such as coupling assembly **301** in FIG. **3**, are depicted. These components may be assembled to form a coupling assembly configured to couple first tube **500** with second tube **502**. First tube **500** and second tube **502** are examples of implementations for first transport member **302** and second transport member **304**, respectively, in FIG. **3**.

As depicted, first tube **500** has first end **504**, and second tube **502** has second end **506**. Further, first tube **500** has first surface **508** and first channel **510**. Second tube **502** has second surface **512** and second channel **514**.

First ferrule **516**, second ferrule **518**, first O-ring **520**, second O-ring **522**, sleeve **524**, and clamshell device **526** are components that may be assembled to form coupling assembly **528**. First ferrule **516** and second ferrule **518** are examples of implementations for first ferrule **326** and second ferrule **328**, respectively, in FIG. **3**. Further, sleeve **524** and clamshell device **526** are examples of implementations for sleeve **340** and clamshell device **346**, respectively, in FIG. **3**.

First ferrule **516**, second ferrule **518**, sleeve **524**, and clamshell device **526** may be comprised of nonmetallic materials having a level of conductivity within a selected range. This range may be, for example, without limitation, between about 1×10^{-4} Siemens/centimeters and about 1×10^{-9} Siemens/centimeters. For example, first ferrule **516**, second ferrule **518**, sleeve **524**, and clamshell device **526** may be comprised of composite materials. In particular, these components may be comprised of composite materials selected such that these components have a level of conductivity within the selected range.

First O-ring **520** and second O-ring **522** are examples of implementations for first O-ring **342** and second O-ring **344**, respectively, in FIG. **3**. In this illustrative example, each of first O-ring **520** and second O-ring **522** is comprised of a viscoelastic material, such as viscoelastic material **332** in FIG. **3**. This viscoelastic material has a level of conductivity within, for example, without limitation, selected range **334** for conductivity **335** in FIG. **3**.

As depicted, coupling assembly **528** has been partially assembled. In particular, first ferrule **516** has been placed around first surface **508** of first tube **500** at first end **504** of first tube **500**. Second ferrule **518** has been placed around second surface **512** of second tube **502** at second end **506** of second tube **502**. Further, first O-ring **520** has been placed around first ferrule **516**, and second O-ring **522** has been placed around second ferrule **518**. In this illustrative example, first O-ring **520** fits into a groove in first ferrule **516**. Second O-ring **522** fits into a groove in second ferrule **518**.

Turning now to FIG. **6**, an illustration of a partially-assembled coupling assembly is depicted in accordance with an illustrative embodiment. In FIG. **6**, sleeve **524** has been placed around first O-ring **520** and second O-ring **522** (not shown in this view) of coupling assembly **528** from FIG. **5**.

When sleeve **524** is placed around these two O-rings, these O-rings are compressed by sleeve **524**. Sleeve **524**, first O-ring **520**, and second O-ring **522** form seal **600** when first O-ring **520** and second O-ring **522** are compressed by sleeve **524**. Seal **600** is an example of one implementation for seal **322** in FIG. **3**.

Seal **600** seals the interface (not shown) between first end **504** (not shown) of first tube **500** and second end **506** (not shown) of second tube **502**. Further, seal **600** forms a conductive pathway between first tube **500** and second tube **502**. As depicted, coupling assembly **528** remains partially assembled without clamshell device **526**.

Turning now to FIG. **7**, an illustration of a fully-assembled coupling assembly is depicted in accordance with an illustrative embodiment. In FIG. **7**, coupling assembly **528** has been fully assembled. In particular, clamshell device **526** has been placed around seal **600** and at least a portion of first ferrule **516** and at least a portion of second ferrule **518** to form the fully-assembled coupling assembly **528**.

With reference now to FIG. **8**, an illustration of a cross-sectional view of a coupling assembly is depicted in accordance with an illustrative embodiment. In this illustrative example, a cross-sectional view of coupling assembly **528** in FIG. **7** taken along lines **8-8** is depicted.

As depicted, seal **600** forms conductive pathway **800** between first tube **500** and second tube **502**. In particular, conductive pathway **800** is formed at interface **802** between first tube **500** and second tube **502**. Interface **802** is between first end **504** of first tube **500** and second end **506** of second tube **502**. First O-ring **520** fits within groove **806** of first ferrule **516**. Second O-ring **522** fits within groove **808** of second ferrule **518**.

In this illustrative example, conductive pathway **800** is formed through first surface **508** of first tube **500**, first ferrule **516**, first O-ring **520**, sleeve **524**, second O-ring **522**, second ferrule **518**, and second surface **512** of second tube **502**. Conductive pathway **800** allows first tube **500**, second tube **502**, and coupling assembly **528** to function as a ground between the two tubes. At least one of first tube **500**, second tube **502**, and coupling assembly **528** may be connected to ground such that conductive pathway **800** may be considered as grounding these two tubes.

With reference now to FIG. **9**, an illustration of a cross-sectional view of a different configuration for a coupling assembly is depicted in accordance with an illustrative embodiment. In FIG. **9**, coupling assembly **528** has a different configuration than the configuration for coupling assembly **528** in FIG. **8**.

As depicted in FIG. **9**, coupling assembly **528** includes third O-ring **900** and fourth O-ring **902** in addition to first O-ring **520** and second O-ring **522** in seal **600**. Third O-ring **900** fits within groove **906** of first ferrule **516**. Fourth O-ring **902** fits within groove **908** of second ferrule **518**. Third O-ring **900** and fourth O-ring **902** could also be elastic or viscoelastic features that are not seals, but could be attached to clamshell device **526** to provide a conductive pathway as described below.

In this illustrative example, third O-ring **900** and fourth O-ring **902** allow seal **600** to form additional conductive pathway **904** between first tube **500** and second tube **502**. In particular, additional conductive pathway **904** is formed through first surface **508** of first tube **500**, first ferrule **516**, third O-ring **900**, clamshell device **526**, fourth O-ring **902**, second ferrule **518**, and second surface **512** of second tube **502**.

Turning now to FIG. **10**, an illustration of a cross-sectional view of another configuration for a coupling assembly is depicted in accordance with an illustrative embodiment. In this illustrative example, seal **600** in coupling assembly **528** comprises only one O-ring instead of two O-rings. As depicted, seal **600** uses O-ring **1000** instead of both first O-ring **520** and second O-ring **522** in FIG. **8**.

With this configuration for seal **600**, conductive pathway **1002** is formed between first tube **500** and second tube **502**. Conductive pathway **1002** is formed through first surface **508** of first tube **500**, first ferrule **516**, O-ring **1000**, second ferrule **518**, and second surface **512** of second tube **502**. As depicted, electrical currents may also flow from first ferrule **516** into sleeve **524**, and into second ferrule **518**.

Turning now to FIG. **11**, an illustration of a cross-sectional view of a different configuration for a coupling assembly is depicted in accordance with an illustrative embodiment. In this illustrative example, seal **600** in coupling assembly **528** comprises gasket **1100**. Further, seal **600** does not include sleeve **524** in this example.

As depicted, gasket **1100** has shape **1102**. Shape **1102** is configured such that first end **1104** of gasket **1100** fits into groove **806** in first ferrule **516**. Further, shape **1102** is configured such that second end **1106** of gasket **1100** fits into groove **808** in second ferrule **518**. Clamshell device **526** may be used to compress gasket **1100** such that gasket **1100** forms seal **600** to seal interface **802** when clamshell device **526** is placed around seal **600**.

In this illustrative example, gasket **1100** forms conductive pathway **1108** between first tube **500** and second tube **502**. Conductive pathway **1108** is formed through first surface **508** of first tube **500**, first ferrule **516**, gasket **1100**, second ferrule **518**, and second surface **512** of second tube **502**.

The illustrations of the different configurations for coupling assembly **528** in FIGS. **5-11** are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be optional.

With reference now to FIG. **12**, an illustration of a process for reducing an intensity of an electrical discharge within a fluid transport system in the form of a flowchart is depicted in accordance with an illustrative embodiment. The process illustrated in FIG. **12** may be implemented using fluid transport system **100** in FIG. **1**. In this illustrative example, fluid transport system **100** may be configured for use in aerospace vehicle **106** in FIG. **1**.

The process begins by operating the aerospace vehicle in which the fluid transport system has an electrical configuration comprising a set of electrical properties in which each electrical property in the set of electrical properties has a value within a selected range (operation **1200**). The process may then reduce an intensity of an electrical discharge within the fluid transport system during operation of the aerospace vehicle to within selected tolerances by the electrical configuration of the fluid transport system (operation **1202**), with the process terminating thereafter.

With reference now to FIG. **13**, an illustration of a process for reducing the energy that can be supplied to an electrical discharge within a fluid transport system in the form of a flowchart is depicted in accordance with an illustrative embodiment. The process illustrated in FIG. **13** may be implemented using fluid transport system **100** in FIG. **1**. In particular, this process may be implemented using tube **201** in FIG. **2**. Tube **201** may be configured for use in aerospace vehicle **106** in FIG. **1**.

The process begins by operating the aerospace vehicle in which a transport member in the fluid transport system in the aerospace vehicle is comprised of a material selected such that the transport member has a resistance within a selected range (operation **1300**). This selected range may include only electrical resistance levels above about 100 kilohms. Further, in some cases, this selected range may also only include electrical resistance levels below about 100 megohms.

The process may then reduce voltages and currents, induced in response to an electromagnetic event that occurs during operation of the aerospace vehicle, along the transport member to within selected tolerances by the resistance of the transport member (operation **1302**), with the process terminating thereafter. Reducing these voltages and currents may reduce the energy that can be supplied to an electrical discharge within the fluid transport system. In this manner, this reduction of the induced voltages and currents may reduce the intensity of an electrical discharge that may occur within the fluid transport system.

With reference now to FIG. **14**, an illustration of a process for dissipating electrostatic charge in the form of a flowchart is depicted in accordance with an illustrative embodiment. The process illustrated in FIG. **14** may be implemented using a coupling assembly, such as, for example, coupling assembly **301** in FIG. **3**.

The process begins by operating the aerospace vehicle such that an electrostatic charge builds up on a surface of at least one of a first transport member and a second transport member in the fluid transport system in the aerospace vehicle (operation **1400**). In one illustrative example, a first end of the first transport member may be coupled to a second end of the second transport member using a connection in the form of a coupling assembly comprising a first fitting, a second fitting, and a seal. The first fitting may be associated with the first end of the first transport member. The second fitting may be associated with the second end of the second transport member.

The seal is placed around the first fitting and the second fitting with the first end of the first transport member positioned next to the second end of the second transport member. The seal is configured to seal an interface between the first end of the first transport member and the second end of the second transport member when the first end and the second end are positioned next to each other.

In one illustrative example, the seal includes a first gasket, a second gasket, and a sleeve. The first gasket is placed around the first fitting, and the second gasket is placed around the second fitting. The sleeve is then placed around the first gasket and the second gasket. The sleeve compresses the first gasket and the second gasket to seal the interface between the first end of the first transport member and the second end of the second transport member. The coupling assembly between the first transport member and the second transport member may be configured to form a conductive pathway between the first transport member and the second transport member.

The process dissipates the electrostatic charge that builds up on the surface of the at least one of the first transport member and the second transport member during operation of the aerospace vehicle, using the conductive pathway between the first transport member and the second transport member (operation **1402**), with the process terminating thereafter. In this manner, the coupling assembly allows the first transport member and the second transport member to be grounded from one transport member to the other. A number of electrical currents may flow from one transport member to the other transport member without interruption and without the level of the electrical currents changing outside of selected tolerances.

The flowchart and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, function, and/or a portion of an operation or step.

In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

Illustrative embodiments of the disclosure may be described in the context of aircraft manufacturing and service method **1500** as shown in FIG. **15** and aircraft **1600** as shown in FIG. **16**. Turning first to FIG. **15**, an illustration of an aircraft manufacturing and service method is depicted in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method **1500** may include specification and design **1502** of aircraft **1600** in FIG. **16** and material procurement **1504**.

During production, component and subassembly manufacturing **1506** and system integration **1508** of aircraft **1600** takes place. Thereafter, aircraft **1600** may go through certification and delivery **1510** in order to be placed in service **1512**. While in service **1512** by a customer, aircraft **1600** is scheduled for routine maintenance and service **1514**, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method **1500** may be performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

With reference now to FIG. **16**, an illustration of an aircraft is depicted in which an illustrative embodiment may be implemented. In this example, aircraft **1600** is produced by aircraft manufacturing and service method **1500** in FIG. **15** and may include airframe **1602** with systems **1604** and interior **1606**. Examples of systems **1604** include one or more of propulsion system **1608**, electrical system **1610**, hydraulic system **1612**, environmental system **1614**, and fuel system **1616**. Fuel system **1616** and hydraulic system **1612** may be implemented using, for example, fluid transport system **100** in FIG. **1**.

Any number of other systems may be included in systems **1604**, depending on the implementation. Although an aerospace example is shown, different illustrative embodiments may be applied to other industries, such as the automotive industry.

Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **1500** in FIG. **15**. For example, tubes, such as plurality of tubes **111** in FIG. **1**, may be manufactured, installed, and/or reworked in aircraft **1600** during at least one of component and subassembly manufacturing **1506**, system integration **1508**, and maintenance and service **1514**.

In one illustrative example, components or subassemblies produced in component and subassembly manufacturing **1506** in FIG. **15** may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft **1600** is in service **1512** in FIG. **15**. As yet another example, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages, such as component and subassembly manufacturing **1506** and system integration **1508** in FIG. **15**. One or more apparatus embodiments, method embodiments, or a combination thereof may be utilized while aircraft **1600** is in service **1512** and/or during maintenance and service **1514** in FIG. **15**. The use of a number of the different illustrative embodiments may substantially expedite the assembly of and/or reduce the cost of aircraft **1600**.

Thus, the different illustrative embodiments provide a method and apparatus for reducing an intensity of an electrical discharge that may occur within a fluid transport system. In one illustrative embodiment, a fluid transport system comprises a plurality of transport members and a number of connections connecting transport members in the plurality of transport members to each other. The plurality of transport members and the number of connections may be comprised of materials selected such that the intensity of an electrical discharge that occurs within the fluid transport system may be reduced to within selected tolerances.

The description of the different illustrative embodiments has been presented for purposes of illustration and description and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other desirable embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A fluid transport system comprising:

a plurality of transport members; and

a number of connections connecting transport members in the plurality of transport members to each other, wherein the plurality of transport members and the number of connections are comprised of materials selected such that an intensity of an electrical discharge that occurs within the fluid transport system is reduced to within selected tolerances and wherein a connection in the number of connections is configured to connect a first transport member in the plurality of transport members and a second transport member in the plurality of transport members and wherein the connection is configured such that an electrical resistance across the connection is less than the electrical resistance through a specified length of at least one of the first transport member and the second transport member.

2. The fluid transport system of claim **1**, wherein the plurality of transport members is a plurality of tubes and wherein each tube in the plurality of tubes is comprised of a material configured to reduce voltages and currents, induced in response to an electromagnetic event, along the tube.

3. The fluid transport system of claim **2**, wherein the material for the tube is selected such that the tube has an electrical resistance within a selected range in which the selected range includes per unit length electrical resistance levels at least one of above about 100 kilohms per meter and below about 100 megohms per meter.

4. The fluid transport system of claim **2**, wherein the material is a non-metallic composite material.

5. The fluid transport system of claim **1**, wherein the connection is a coupling assembly comprising:

a first fitting associated with a first end of the first transport member;

a second fitting associated with a second end of the second transport member; and

a seal configured for placement around the first fitting and the second fitting when the first end of the first transport member is positioned relative to the second end of the second transport member, wherein the seal is configured to seal an interface between the first end of the first transport member and the second end of the second transport member.

6. The fluid transport system of claim **5**, wherein the seal is comprised of a material configured such that the seal has a level of conductivity within a selected range and such that the connection forms a conductive pathway between the first transport member and the second transport member.

7. The fluid transport system of claim **6**, wherein the conductive pathway allows electrostatic charge that builds up on at least one of the first transport member and the second transport member to be dissipated.

8. The fluid transport system of claim **1**, wherein a first transport member of the plurality of transport members, a second transport member of the plurality of transport members, and a connection of the number of connections form a conductive pathway grounding the first transport member and the second transport member without directly grounding the connection to a structure.

9. The fluid transport system of claim **1**, wherein resistance within a selected range is distributed evenly over individual intervals of a length of the plurality of the transport members.

10. The fluid transport system of claim **1**, wherein each transport member in the plurality of transport members has a respective resistance within a selected range, wherein each respective resistance is distributed evenly over a respective length of each respective transport member.

11. A fluid transport system having an electrical configuration configured to reduce an intensity of an electrical discharge that occurs within the fluid transport system, the fluid transport system comprising:

a plurality of tubes, wherein a tube in the plurality of tubes is comprised of a composite material selected such that the tube has a resistance within a selected range configured to reduce voltages and currents, induced in response to an electromagnetic event, along the tube to within selected tolerances; and

a number of coupling assemblies configured to couple tubes in the plurality of tubes to each other, wherein a coupling assembly in the number of coupling assemblies comprises:

a first fitting associated with a first end of a first tube in the plurality of tubes;

a second fitting associated with a second end of a second tube in the plurality of tubes; and

a seal configured for placement around the first fitting and the second fitting when the first end of the first tube is positioned relative to the second end of the second tube, wherein the seal is configured to seal an interface between the first end of the first tube and the second end of the second tube and provide a conductive pathway between the first tube and the second tube to allow electrostatic charge that builds up on at least one of the first tube and the second tube to be dissipated, and wherein the first tube, the second tube, and the coupling assembly form the conductive pathway grounding the first tube and the second tube without directly grounding the coupling assembly to a structure.

12. The fluid transport system of claim **11**, wherein reducing the voltages and currents, induced in response to the electromagnetic event, along the tube reduces energy available to the electrical discharge.

13. The fluid transport system of claim **11**, wherein dissipating the electrostatic charge that builds up on the at least one of the first tube and the second tube reduces energy available to the electrical discharge.

14. A method for reducing an intensity of an electrical discharge that occurs within a fluid transport system in an aerospace vehicle, the method comprising:

operating the aerospace vehicle, wherein the fluid transport system in the aerospace vehicle is comprised of materials selected such that the fluid transport system has an electrical configuration, wherein the fluid transport system comprises a plurality of transport members and a plurality of connections connecting transport members in the plurality of transport members to each other, wherein the plurality of transport members and the plurality of connections are comprised of materials selected such that an intensity of the electrical discharge that occurs within the fluid transport system is reduced to within selected tolerances, and wherein a connection in the plurality of connections is configured to connect a first transport member in the plurality of transport members and a second transport member in the plurality of transport members and wherein the connection is configured such that an electrical resistance across the connection is less than the electrical resistance through a specified length of at least one of the first transport member and the second transport member; and

reducing the intensity of the electrical discharge that occurs within the fluid transport system during operation of the aerospace vehicle to within selected tolerances by the electrical configuration of the fluid transport system.

15. The method of claim 14, wherein the step of operating the aerospace vehicle comprises:

operating the aerospace vehicle, wherein the electrical configuration of the fluid transport system comprises a set of electrical properties in which each electrical property in the set of electrical properties has a value within a selected range.

16. The method of claim 15, wherein the step of operating the aerospace vehicle comprises:

operating the aerospace vehicle such that an electrostatic charge builds up around a surface of at least one of the first transport member and the second transport member in the fluid transport system in the aerospace vehicle.

17. The method of claim 16, wherein the step of reducing the intensity of the electrical discharge that occurs within the fluid transport system during the operation of the aerospace vehicle to within selected tolerances comprises:

dissipating the electrostatic charge using the connection in the fluid transport system between the first transport member and the second transport member.

18. The method of claim 17, wherein dissipating the electrostatic charge using the connection in the fluid transport system between the first transport member and the second transport member includes the first transport member, the second transport member, and the connection forming a conductive pathway grounding the first transport member and the second transport member without directly grounding the connection to a structure.

19. The method of claim 14, wherein the step of operating the aerospace vehicle comprises:

operating the aerospace vehicle, wherein each transport member of the plurality of transport members in the fluid transport system in the aerospace vehicle is comprised of a material selected such that each transport member of the plurality of transport members has an electrical resistance that is above about 100 kilohms and below about 100 megohms per meter.

20. The method of claim 19, wherein the step of reducing the intensity of the electrical discharge that occurs within the fluid transport system during the operation of the aerospace vehicle to within selected tolerances comprises:

limiting current, induced in response to an electromagnetic event that occurs during operation of the aerospace vehicle, along each transport member of the plurality of transport members to within selected tolerances by the electrical resistance of each transport member of the plurality of transport members, wherein limiting the current along each transport member of the plurality of transport members limits the current that can be supplied to the electrical discharge.

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